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R. W. Brock, Director

Memoir No. 21.

THE GEOLOGY AND ORE DEPOSITS
OF
PHOENIX
BOUNDARY DISTRICT, BRITISH COLUMBIA

BY

O. E. LeRoy

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LETTER OF TRANSMITTAL.

To R. W. Brock, Esq.,
Director Geological Survey,
Department of Mines.

Sir,—I beg to submit the following Memoir on the Geology and Ore Deposits of Phoenix, Boundary district, British Columbia.

I have the honour to be, sir,
Your obedient servant,
(Signed) **O. E. LeRoy.**

Ottawa, February, 1911.

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THE GEOLOGY AND ORE DEPOSITS
OF
PHOENIX
BOUNDARY DISTRICT, BRITISH COLUMBIA

BY

O. E. LeRoy.

CHAPTER I.

INTRODUCTION.

General Statement.

The Boundary district entered the ranks of the copper producing centres of British Columbia in 1900, and ever since has held the leading place in the Province, and for some years has been the premier copper producing district in Canada. According to the annual reports to the Minister of Mines of British Columbia, the ore mined and smelted in the Boundary district during the first decade (1900 to 1909) of production, contained 247,895,303 pounds of copper, as well as an important amount of gold and silver.

The principal mines of the district are: the Knob Hill-Ironsides, Gold Drop, Rawhide, Monarch, Snowshoe, and War Eagle, situated at Phoenix; the Oro Denoro and Emma at Summit; and the Mother Lode and Sunset at Deadwood near Greenwood (Fig. 1, p. 13).

Phoenix afforded exceptional facilities for the study of the relations of the ore bodies through the extensive underground development of the several mines, and a detailed survey was made of the camp during the summer of 1908. The primary object of the survey was to secure all available information regarding the enormous low grade ore bodies and their geological relations, which, when properly correlated, it was hoped might be of material assistance to mining development at Phoenix. It was also hoped that the broader relations could be applied with benefit at other mines, operated elsewhere in the district, where the ore bodies had similar associations. In a measure it is felt that such practical results have been obtained, and that much of the general information relating to the ore bodies may be used to advantage elsewhere in the district, in the case of mineralized zones similar to those occurring at Phoenix.

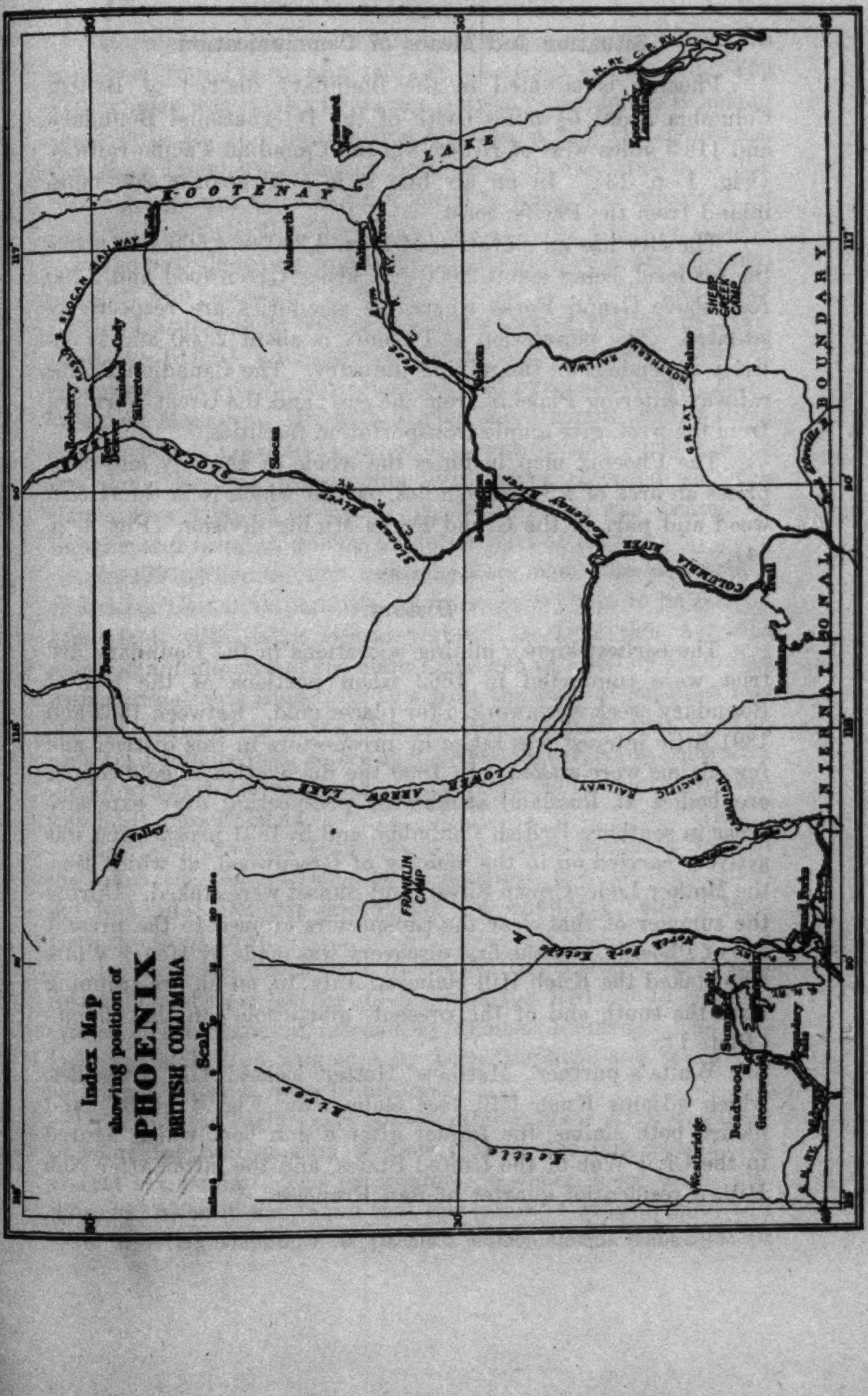
Field Work and Acknowledgments.

The particular area studied at Phoenix and in the vicinity is about 2 square miles in extent and includes all the principal mines of the camp. This report is based on the results of 3½ months field work in 1908, supplemented by information secured during brief visits to Phoenix in 1909 and 1910.

The topographical work was in charge of Mr. W. H. Boyd, the resulting map being published on a scale of 400 feet to an inch with a 20 foot contour interval. The geological work, both areal and economic, was in charge of the writer, who was assisted by Mr. C. W. Drysdale. The mapping of the areal geology was controlled by transit and stadia surveys, while the mine plans of the several companies served as a basis for geological work underground.

Acknowledgments are due to the officials of the Granby Consolidated Mining, Smelting, and Power Company, the Consolidated Mining and Smelting Company of Canada, and the Dominion Copper Company (now the New Dominion Copper Company), for their courteous and willing co-operation in permitting free access to all the underground workings, and the use of all available information connected with the mines. Permission was kindly given by the officials to publish such mine plans as appear throughout the report. The writer wishes to acknowledge his especial indebtedness to Messrs. A. B. W. Hodges, O. B. Smith, and C. M. Campbell for helpful suggestions and criticisms during the progress of the work, to Mr. Charles Biesel who placed two houses at the disposal of the party for the summer of 1908, to Mr. George Rumberger for information relating to the early history of Phoenix, and to the Messrs. McRae for permission to reproduce two of their photographs (Plate I, Plate IIA.)

Fig. 1


Index Map
showing position of
PHOENIX
BRITISH COLUMBIA
Scale
20 miles
KOOTENAY LAKE
Kaslo
Ainsworth
Balfour
Procter
West Arm
Nelson
Crawford Bay
Kootenay Landing
KASLO & SLOCAN RAILWAY
Sandon
Cody
Rosebery
New Denver
Silverton
SLOCAN LAKE
Slocan
Slocan River
Kootenay River
Robson
COLUMBIA RIVER
Trail
Rossland
Salmo
SHEEP CREEK CAMP
GREAT NORTHERN RAILWAY
INTERNATIONAL BOUNDARY
Burton
LOWER ARROW LAKE
CANADIAN PACIFIC RAILWAY
Christina Lake
Grand Forks
FRANKLIN CAMP
North Fork Kettle R.
Eholt
Phoenix
Greenwood
Deadwood
Midway
Westbridge
Kettle River

Situation and Means of Communication.

Phoenix is situated in the Boundary district of British Columbia about 6½ miles north of the International Boundary and 118·5 miles west of Nelson via the Canadian Pacific railway (Fig. 1, p. 13). In an air line it is a little over 200 miles inland from the Pacific coast.

The city has an elevation of from 4,300 to 4,600 feet above the sea-level, being about 2,000 feet above Greenwood and 2,700 feet above Grand Forks where the smelteries are respectively situated. The population at Phoenix is about 2,000 and is entirely dependent on the mining industry. The Canadian Pacific railway entering Phoenix from the east, and the Great Northern from the west, give ample transportation facilities.

The Phoenix map includes the whole of the city and comprises an area of 1·9 square miles, part of which is in the Greenwood and part in the Grand Forks Mining division (Fig. 4, p. 54).

History.

The earliest known mining operations in the Boundary district were conducted in 1862 when portions of the bed of Boundary creek were worked for placer gold. Between 1862 and 1891 little interest was taken by prospectors in this district and few claims were staked. In 1890 the discoveries of gold-copper ore bodies at Rossland stimulated prospecting over extensive areas in southern British Columbia, and in 1891 prospecting was actively carried on in the vicinity of Greenwood, at which time the Mother Lode, Crown Silver, and Sunset were staked. During the summer of that year the prospectors crossed to the present site of Phoenix, and the first discovery was made by Henry White who staked the Knob Hill claim on July 15, on an ore-cropping near the south end of the present 'glory hole' on that claim.[1] (Plate I).

White's partner, Matthew Hotter, located Old Ironsides, which adjoins Knob Hill (see claim map, Fig. 4, p. 54) and named both claims, the former after a gun boat which figured in the Civil War of the United States, and the latter after Nob Hill, a residential quarter of San Francisco.

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[1] Personal communication from Mr. G. W. Rumberger.

During the season of 1891, most of the ground which has since been found to contain valuable ore bodies was located. The Stemwinder was staked by James Attwood and James Schofield about July 25, and the fraction between it and Old Ironsides, two days later, by Edmond Lefebvre. It was known as the Silver King, and after being allowed to lapse was relocated by Robert Dengler as the Phoenix from which the city was named.

The next discovery was made by Joseph Taylor and Stephen Mangott who located the Brooklyn on July 31. A few days later Robert Dengler and William Douglas located the North Star, (now the Idaho), and about the same time George Rumberger discovered the ground at present covered by the Snowshoe, Rawhide, and Monarch. He, with Taylor and Mangott, staked three claims (600 × 1,500 feet), on which considerable surface work was done, but the assessments were never recorded and the claims were allowed to lapse. The War Eagle was located by Dengler and Douglas during the latter part of August.

In 1891, when the first locations were made, the Mining Act of British Columbia permitted the size of a claim to be 600 by 1,500 feet, with extra lateral rights. In 1892 this Act was repealed and the size of the claims changed to 1,500 by 1,500 feet with vertical side lines. At this time the base of supplies was Marcus, in the State of Washington, about 75 miles distant. The pack trail followed the valley of the Kettle river, connecting with the Dewdney trail at Grand Forks, from which a branch trail was built into Phoenix.

In 1893, Thomas Humphrey and James Keightly located the Monarch; Robert Dengler, D. McInnes, and William Gibbs the Rawhide; Dengler and Gibbs the Snowshoe; and Joseph Hetu the Gold Drop.

In 1894, the North Star was relocated by John Meyer and George Rumberger as the Idaho, and the Red Cloud was relocated as the Standard fraction by Thomas Johnston. The Victoria was staked on August 1 by John Stephens and the Aetna on August 25 by George Rumberger.

During the early years considerable surface work was done in trenching and sinking shallow pits on the outcrops of the several ore bodies. The prospectors, however, were much discouraged when it was found that the values in copper, gold, and silver were so low, and owing to this, many claims were allowed to lapse which were afterwards relocated by others. A renewed activity was the outcome of the discovery that the ores were practically self fluxing, which, combined with the apparently enormous size of the deposits, began to attract the capital necessary for proper development. It was recognized at an early period that it was no poor man's camp, and that a large amount of time and capital must be expended in developing the ore bodies, and in the building of smelters, before the properties could be placed on a paying basis.

In 1896 the Miner-Graves syndicate commenced development work on the Old Ironsides-Knob Hill ore body, and preparations were made later on for the building of a smeltery at Grand Forks. By purchase and consolidation the original company became the Granby Consolidated Mining, Smelting, and Power Company, controlling the most important group of mines at Phoenix, with a smeltery and converting plant at Grand Forks The first shipment of ore was made in July, 1900, and the first furnace blown in on August 21 of that year. Other consolidations and purchases of the remaining valuable properties at Phoenix were made by the Consolidated Mining and Smelting Company of Canada and the New Dominion Copper Company. The above three Companies, therefore, control all the ore deposits of economic value in the area of the Phoenix map, detailed descriptions of which will be found in another part of this report (Chap. VI, p. 71). The camp was known as the Greenwood camp until 1898 when the first post-office was established at Phoenix; the latter name, however, has had a partial recognition since 1895. It was incorporated as a city in 1900. The Canadian Pacific railway extended its line into Phoenix in 1898, and the Great Northern in 1904.

Previous Work.

In 1901, Mr. R. W. Brock of the Geological Survey Staff made a reconnaissance survey of a portion of the Boundary district; and in 1902 geologically mapped a belt about 13 miles wide along the International Boundary extending from Grand Forks west to Midway, comprising an area of over 200 square miles. Dr. R. A. Daly, geologist for the Boundary Commission, at a later date geologically examined a 5 mile belt along the International Boundary. His report, however, has not yet been published, but is listed in the bibliography below.

Bibliography.

The following list of references contains the most important papers and reports bearing on the geology, ore deposits, and mining and metallurgical methods in vogue in this district.

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The Copper Mines of the World, pp. 217-220.
Ore Deposits near Igneous Contacts.
Trans. Amer. Inst. Min. Eng., Vol. 33, 1902, pp. 715-747.

CHAPTER II.

SUMMARY AND CONCLUSIONS.

General Geology.

Palæozoic.—The oldest rocks occurring at Phoenix which have been termed the Knob Hill group, consist of a complex of various clastic rocks of igneous origin, porphyrites, and a minor development of sediments and limestone. The rocks are massive throughout and there is an absence of structural features such as bedding and banding indicating stratigraphic sequence. The group is placed in the Palæozoic without a fixed position in the time scale in that era.

The Brooklyn formation overlies the Knob Hill group and consists of non-fossiliferous crystalline limestones, tuffs, and argillites. A very large portion of the limestone and most of the tuffs have been replaced by silica, giving a zone of jasperoids. Another portion of the limestone has been replaced by the lime silicates epidote, garnet, etc. The formation, therefore, admits of a threefold division: the remnants of crystalline limestone, a zone of jasperoids, and a zone consisting essentially of lime silicates, the latter containing all the important bodies of low grade copper ore. The Rawhide formation overlies the Brooklyn conformably and consists entirely of argillites.

These two formations have been grouped together as the Attwood series, and tentatively placed in the Carboniferous, though direct evidence as regards age is lacking owing to the absence of fossils. As no marked break occurs between the Brooklyn formation and Knob Hill group it is possible that the latter may be but little older than the Attwood series and, possibly, also of upper Palæozoic age.

Mesozoic.—The Mesozoic is represented by a few small intrusions of syenite and syenite porphyry, which from field relations are supposed to be connected with the granodiorite batholith of Jurassic (?) age, so widely developed elsewhere in the district.

Tertiary.—The earliest rocks of the Tertiary are sediments, of Oligocene age, termed the Kettle River formation, and overlie the Brooklyn formation unconformably. They consist of conglomerates, sandstones, and shales, some of the latter containing plant remains altered to lignite, as well as thin seams of lignite. The continuity of the formation, once widespread, is now broken as the result of erosion, and the strata now occupy isolated areas, one of which occurs at Phoenix.

Overlying in part the Kettle River formation, and in part the Brooklyn formation and Knob Hill group, are the lavas of the Midway Volcanic group, the age of which is supposed to be Miocene. The lavas range in composition from trachyte to basalt, and, like the Kettle River formation, occurred as continuous and widespread exposures, but are now represented by isolated areas, one of which occurs at Phoenix. Dykes, sills, and stocks of pulaskite, porphyry (alkaline syenite porphyry), and augite porphyrite are intrusive in all the rock series including the lavas. The former is the younger, and represents the last phase of igneous activity in this portion of the district.

Ore Deposits.

Phoenix is the most important copper camp in Canada and the mines, up to July 1, 1910, have produced and shipped over 7,000,000 tons of ore.

The ore bodies occur in a mineralized zone which represents a portion of the Brooklyn limestone replaced by epidote, garnet, etc. The zone is separated into isolated areas which occupy trough-like basins in the jasperoids and limestones (Figs. 10, 18.)

The ore bodies lie at different horizons in this zone though generally favouring the lower and outer portions, and may be considered simply as portions of the mineralized zone in which the copper ore has been sufficiently concentrated to form workable deposits. The ore bodies range in size from lenses about 100 feet long and 20 feet thick to extensive masses like the main ore body of the Knob Hill-Ironside mine, which is about 2,500 feet long and has a maximum thickness of 125 feet and a known width of 900 feet. The altitude of the ore bodies varies in different bodies, and at different points in the same body, from vertical to almost horizontal. There is a pronounced flattening of the dip with depth. The foot-wall is usually jasperoid, occasionally limestone, and, in one instance, the quartzose rocks of the Knob Hill group. As a rule, the commercial foot-wall coincides with the structural. The hanging-wall is almost invariably a commercial one, though the pay ore is usually sharply marked off from the lower grade by a gouge-filled fissure or 'slip.'

The ore throughout is remarkably uniform and is almost self fluxing. It consists of finely disseminated chalcopyrite, with pyrite and hematite (specularite), in a gangue composed essentially of epidote, garnet, quartz, calcite, and chlorite. Magnetite occurs in distinct masses, or lense-like bodies, both in, and along the borders of the main ore bodies. In the case of the Monarch deposit magnetite forms one of the main ore bodies. The chalcopyrite carries all the copper, gold, and silver values, the average ore containing from 1·2 to 1·6 per cent of copper with about $1.00 in gold and silver to the ton. The mineralized zone comprises a portion of a zone of contact metamorphism in the limestone of the Brooklyn formation. In the absence of any closely associated masses of igneous rocks, the hypothesis is advanced, that the metasomatic replacement of the limestone, and the deposition of ore have been brought about by solutions, derived from some unit of the granodiorite batholith. The solutions, given off at temperatures above the critical, and carrying silica, alumina, and ferric iron with copper and iron sulphides at a later stage, traversed the limestone in lateral and lateral descending directions, gradually replaced the limestone by epidote, garnet, etc., and deposited the ore uniformly over extensive areas, thus forming the large low grade bodies. The overlying rocks were subsequently removed, which left portions of the ore bodies outcropping at the surface. The fact that the ore bodies are comparatively shallow, and that they give out rather sharply with depth, tends to confirm the view that the solutions were descending rather than ascending. The probable age of their formation is provisionally placed in the Jurassic.

In the commercial development of the ore bodies the initial work is done by diamond drilling by means of which the broad outlines of the bodies are ascertained. The ore is mined by a system of glory holes and quarries along the outcrops, and by the pillar and room method in the underground workings.

Future of District.

The mineralized zone of Phoenix has been well prospected and by such methods as to render it impossible that any large body remains undiscovered. The main ore bodies of the camp have all been located, though closer intervals in prospect drilling may result in the discovery of smaller bodies, which, if favourably situated, may be worked to advantage.

In other localities throughout the Boundary district where limestone occurs associated with a mineralized zone of similar character ore bodies may yet be found by intelligent and scientific prospecting. They cannot, however, in the initial stages, be attacked by the ordinary tunnelling and shaft methods, but should first be proved by diamond drilling, especially as it is known that some bodies do not outcrop at the surface. The average prospector has not the capital necessary for developing ore bodies of this class; this must be left to companies of large capital who can afford to prove or disprove areas of apparent promise.

CHAPTER III.

GENERAL CHARACTER OF THE DISTRICT.

Topography.

REGIONAL.

The Boundary district of British Columbia as far west as Kettle river lies within the Columbia system of the North American Cordillera.[1] In subdividing the Columbia system into groups, Daly includes under the term Midway mountains that portion of the Boundary district lying between Grand Forks and the Kettle river, the east and west boundaries being the North fork of the Kettle, and the Main Kettle rivers respectively. (See Fig. 1, p. 13.).

The Midway group is characterized by comparatively low mountains which usually show uniformity of summit levels at a general elevation of 5,000 feet. When broadly viewed, they appear as rounded ridges or dome-shaped summits, the crests of which are below the limits of intense alpine erosion (Plate II, A. p. 24). According to Brock[2], this uniformity of elevation is believed to be due mainly to the wearing down of the once more rugged and lofty peaks and ridges by processes of erosion, which, above timber line, arise from rapid and extreme changes in temperature—hot days succeeding cold and frosty nights—acting on rocks not protected by soil or vegetation. The rocks thus broken into fragments of varying size are moved down the slopes by gravity, with intermittent assistance from rainfall and snow slides. This process leaves the upper portions of the ridges and peaks bare and covers the lower slopes with a heavy layer of rock waste, which assumes a grade proportional to the size of the fragments. As the peak or ridge is worn down to the base of the zone of rapid erosion the processes work more slowly, and the consequent lag permits other and higher peaks and ridges to be cut down to approximately the same level before the former ones have retreated much below it.

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[1] R. A. Daly. Nomenclature of the North American Cordillera between the 47th and 53rd parallels of latitude. The Geographical Journal, Vol. 27, 1906, pp. 586-606.

[2] Brock, R. W. Sum. Rep. Geol. Sur. of Can., 1902, pp. 93-94-A.

These processes have also been considered in some detail by Daly and have been brought forward as an alternative to the peneplain hypothesis.[1]

This regularity of ridge form has been further modified by lava flows during the Tertiary period, and by glacial erosion during the Pleistocene.

The valleys of the district form a well-marked longitudinal and transverse system, the former being of the broader U-shaped type, with the valley sides usually flanked by series of terraces or benches. The tributaries usually flow with steep gradients in narrower, V-shaped valleys (see Twin Creek valley, Plate II A.). The northern slopes of the ridges are usually well wooded, while the southern are more often open and grassy. The eastern and western slopes may be either forested or open and park like. The higher ridges and the narrower valley bottoms are the better watered and, usually, the more densely wooded.

The district as a whole has a deficient precipitation and to ensure success in the cultivation of grains, fruits, and vegetables irrigation is generally necessary on the bottom lands and is imperative on the bench lands. At Midway, where it is rather dryer than elsewhere in the district, the mean precipitation for the years between 1894 and 1902 amounted to 12·7 inches of rain per annum. The mean temperatures for the years from 1896 to 1902 were: for the month of January, 20·5° F.; for July 65°; and an annual mean of 43 degrees.

LOCAL.

Phoenix is situated partly in the basin at the head of Twin creek and partly on the divide between Twin, an unnamed tributary of Fourth of July creek, and Deadman creek (Plate II A.). The immediate vicinity is broadly dome-shaped, broken by the basin of Twin creek which is surrounded by a rim of relatively

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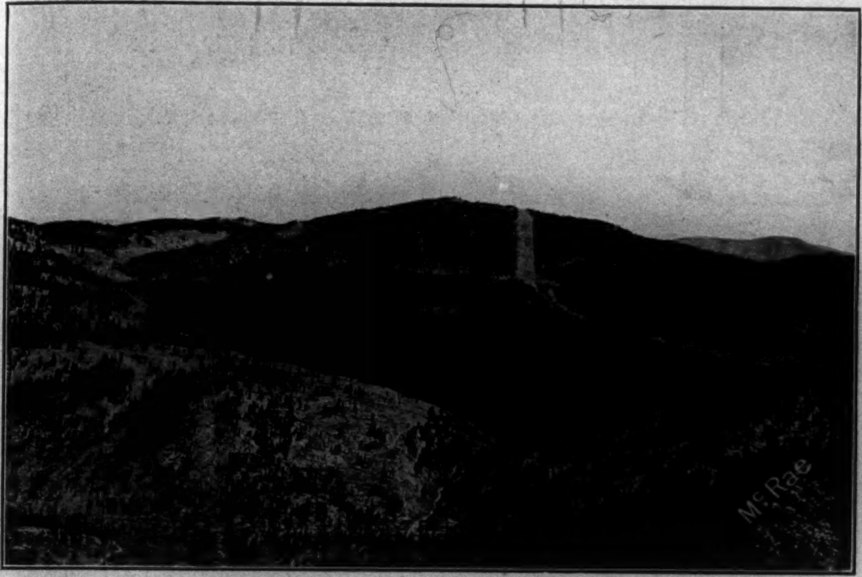
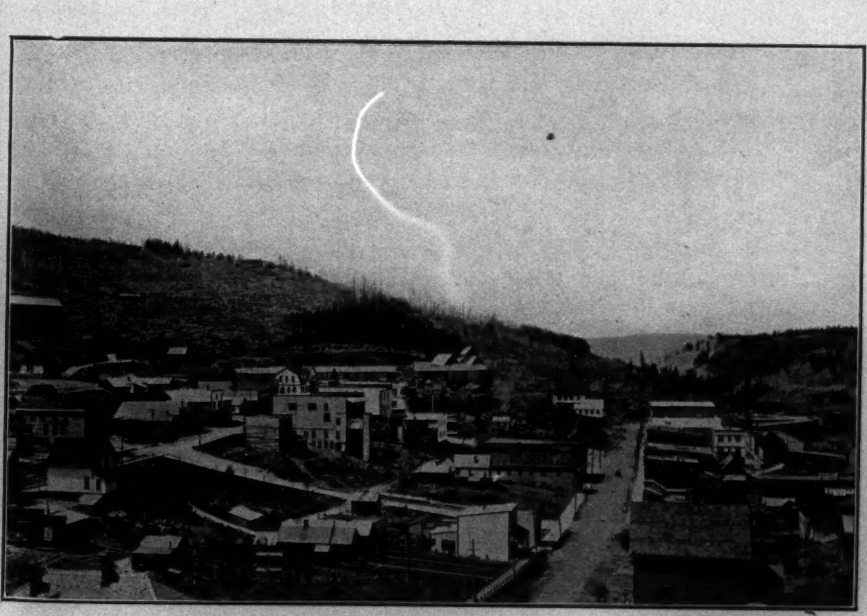
[1] R. A. Daly, The Accordance of Summit Levels among Alpine Mountains. Jour. of Geol., Vol. 13, pp. 105-125.

PLATE II.



(*a*) Phoenix, upper left; Greenwood, lower centre.



(*b*) Phoenix, looking west, 1909.

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prominent ridges grouped in the form of a compressed crescent open to the west.

The ridge to the south culminating with Knob hill attains elevations from 4,800 to 5,200 feet above sea-level. Montezuma and Deadman ridges, the north and northeast rims of the basin, are between 4,800 and 4,900 feet above sea-level and are separated from one another by the pass at Deadman gulch. A low pass separates Deadman from Knob Hill ridge through which the Canadian Pacific railway enters the city. The basin itself is relatively narrow and its slopes comparatively steep. Except for some short stretches along the length of the basin there is an entire absence of level ground. The minor inequalities of the ridge slopes give a kind of subdued ruggedness to the area, intensified locally by low escarpments, due primarily to geological structure.

The ridges and basin were densely wooded when the first prospectors arrived, but the early demand for timber for mining and building purposes, and the ravages of forest fires, have reduced the available reserves to small limits. The chief woods are pine, tamarack, fir, and spruce.

The climate of Phoenix is exceptionally fine, the altitude having a moderating effect on the extremes prevalent in the valleys. In summer the temperature rarely exceeds 90 degrees, and on account of the dryness of the atmosphere the heat is never oppressive, while during the winter zero temperatures are infrequent.

CHAPTER IV.

GENERAL GEOLOGY.

Introduction.

The geological formations developed in the Boundary district were first classified by Brock and outlined in a preliminary report in 1902.[1] In subsequent work by Daly, the results of which have not yet been published, certain correlations were made connecting some of the rock groups with others occurring to the east of the Boundary district. The detailed work at Phoenix has afforded no additional information regarding the ages of the several formations developed there, and the general classification is based on the broader work of Brock and Daly. Attwood, Kettle river, and Midway are names used by Daly in his general work and by the writer, when applicable, in the Phoenix area.

Summary Description of Formations.

PALÆOZOIC.

KNOB HILL GROUP.

The oldest rocks at Phoenix form the Knob Hill group, which comprises a complex of highly altered rocks of igneous origin with minor developments of sediments. Porphyrites, tuffs, breccias, and cherts with small lens-like masses of argillite and limestone are included in this group. The main alterations have been due to complicated faulting accompanied by shearing and widespread silicification. The group on the whole is essentially siliceous in character. A definite position as regards age cannot at present be given to the group but it is possible that it is not much older than the immediately succeeding series.

ATTWOOD SERIES.

The Attwood series admits of a division into two formations in the Phoenix area. The lower or Brooklyn formation consists essentially of limestone and its altered equivalents

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[1] Brock, R. W. Preliminary Report of the Boundary Creek District, Sum. Rep. Geol. Sur. of Canada, 1902, pp. 92-138 A, Map No. 828.

(jasperoids and epidote-garnet rocks), with some tuffs and argillites. Economically it is the most important formation and contains all the principal ore bodies. The upper or Rawhide formation overlies the Brooklyn conformably and consists entirely of argillites. The Attwood series is considered by Daly to be, possibly, the equivalent of the Carboniferous series in the Rossland mountains, and has, therefore, been so placed provisionally.

The contact between the Brooklyn formation and the Knob Hill group is not marked by a stratigraphical unconformity; the jasperoids of the former lie on the cherty rocks of the latter, and the two appear to have been welded together by the processes of silicification, although lithologically, the line separating them is usually quite distinct.

MESOZOIC.

JURASSIC (?)

The granodiorite batholith of Jurassic (?) age so extensively developed to the north and west of Phoenix, has no typical representative in the immediate vicinity, though it probably underlies the area at no great depth. A small mass of syenite and dykes of syenite porphyry which are here intrusive in the Palæozoic rocks, have been referred to this period from their similarity to masses and dykes which occur in association with exposures of the batholith elsewhere in the district.

TERTIARY.

The early Tertiary (Eocene) was probably a period of vigorous erosion during which the lofty mountains of the later Mesozoic time were reduced to mature forms, possibly not differing greatly from those of the present time.

KETTLE RIVER FORMATION.

The earliest rocks of the Tertiary are a sedimentary series deposited in the rivers and lakes. The formation, once extensive through the district, is now exposed only in isolated patches, one of which occurs in the Phoenix area, resting unconformably on the Brooklyn formation. The rocks are conglomerates, sandstones, and shales, with interbedded tuffs in certain localities. The sandstones and shales, locally, contain small seams of impure lignite and plant remains of Oligocene age.

MIDWAY VOLCANIC GROUP.

To Miocene time is referred the period of wide-spread volcanic activity when apparently a great part of the Boundary district was covered by a varying thickness of successive flows of lavas which range in composition from basalt to trachyte. East of Midway the lava cap is represented only by scattered, isolated exposures one of which occurs at Phoenix, overlying unconformably parts of the Knob Hill group and Kettle River and Brooklyn formations. This group, as well as all the older rocks, is cut by a series of dykes, sills, and stocks of alkaline syenite porphyry (pulaskite) and augite porphyrite, the former being the younger of the two. They appear to be genetically connected with the lavas and are apparently the intrusive equivalents of certain types of the extrusive rocks. Warping and faulting accompanied and followed the period of lava flows.

QUATERNARY.

The Phoenix area is comparatively free from any great thickness or continuous mantle of drift. The thickest deposits are in the basin of Twin creek and have not been found to exceed 35 feet. Boulder clay was not observed, the material being re-sorted glacial drift consisting of rudely stratified sands, clays, and gravels, the latter containing pebbles chiefly of local rocks. Along part of the north border of the area of the map and in the northeast corner, sands and gravels predominate. The stratification becomes more distinct and better developed in passing to the west, down the valley of Twin creek. The ridges are glaciated to their summits, though later weathering has obscured the distinctness of grooves and striæ which show the ice movement locally to have been in the direction S. 26° E. The deposits are of little importance and have not been closely studied.

Table of Formations.

Quaternary.	Glacial and Recent.	Modified drift, clays, sands, gravels.
Tertiary.	Miocene?	Pulaskite porphyry (alkali syenite porphyry), dykes, and sills.
		Augite porphyrite in stocks, dykes, and sills.
		Midway Volcanic group. Lavas. Basalt, andesite, trachyte. (Only trachytes occur at Phoenix).
	Oligocene.	Kettle River formation— Conglomerates, sandstones, shales.
Mesozoic.	Jurassic?	Augite syenite, and syenite porphyry in dykes and masses probably connected with main granodiorite batholith of the district.
Palæozoic.	Carboniferous?	Rawhide formation— Argillites.
	Attwood series.	Brooklyn formation— Crystalline limestone and calcareous shales with some argillites and tuffs. In part replaced by silica forming jasperoids, and in part by lime silicates.
		Knob Hill group— Porphyrites, breccias, tuffs, silicified ash rocks, cherts with small lenses of argillites and limestones. In the group is included a few later dykes and sills of hornblende and augite porphyrite.

Detailed Description of Formations.

PALÆOZOIC.

INTRODUCTION.

The Palæozoic is represented in the Phoenix area by the Knob Hill group and the Attwood series, the latter being subdivided into the Brooklyn and Rawhide formations. The Knob Hill group has not been assigned a definite position in the time scale though it is probable that it is but little older than the Attwood series, which is provisionally placed by Daly in the Carboniferous. No stratigraphical unconformity was seen at any of the exposed contacts between the Knob Hill group and the Attwood series. The rocks of both at the contact have been welded together by the processes of silicification.

KNOB HILL GROUP.

Distribution.—The rocks of the Knob Hill group form a broadly elliptical trough-like fold the central portion of which is buried beneath younger strata while the outcropping edges or rim appear in the four corners of the map. This fold may be a portion of a syncline with an approximately north and south trend, but it was not traced beyond the map boundaries. (General map, section A-A).

Thickness.—No means were found to determine the actual or even approximate thickness of the group, but from the cores from vertical drill holes, it is known to be at least 1,200 feet thick.

Lithology.—The rocks of the group form a complex mainly of igneous origin and consist of usually much altered porphyrites, breccias, tuffs, cherts, and a few lens-like masses of argillite and limestone. The group represents essentially a period of volcanic activity with only traces of intervals during which true sediments were deposited. Cherts, tuffs, and porphyrites are the predominant rock types.

The rocks of the group are prevailingly of a dark greenish grey or dark grey colour, weathering to lighter tones. They are usually finely jointed, and brittle, with a conchoidal fracture.

The alterations which the rocks have undergone have been so pronounced that the various types as a rule appear to merge into one another and their individual determinations depend largely on microscopic examinations.

Cherts.—The cherts comprise the greater part of the group and show but little variation in type. They vary in colour from dark grey to black, and occur in both massive and brecciated forms; not distinguished except microscopically. In the cores of the diamond drill holes there is apparent uniformity in composition for hundreds of feet as evidenced by rough determinations of the silica content, which averages about 90 per cent. Microscopically, they are seen to be made up of rounded and irregular, indefinite areas of chalcedonic quartz associated with some black indeterminate material which evidently gives the colour to the darker types. Minute veinlets of quartz and some of calcite with pyrite traverse the rocks in an extensive and intricate net work. The rocks were probably fine tuffs, ash beds, with possibly some fine sediments, in which the original constituents have been replaced by siliceous aggregates.

Tuffs.—The tuffs have a comparatively small distribution and pass insensibly into the cherts on the one hand and on the other into fine breccias of the same mineralogical composition. They are medium to fine grained dark greenish grey rocks which weather to lighter tones with brownish tinge. The quartz grains in the tuffs and the quartz and feldspar in the case of the coarser types or breccias stand in relatively high relief on the weathered surfaces. Microscopically the rocks consist of fragments of quartz and very turbid feldspar (mainly plagioclase) in a matrix of the secondary minerals, chlorite, calcite, pyrite, magnetite, and quartz.

Porphyrites.—The older series of porphyrites probably represent in part lava flows contemporaneous in age with the tuffs and breccias; in part intrusive sills and dykes of a slightly later age. They are all, however, so highly altered that in most cases their origin can only be determined with difficulty. They closely resemble the tuffs and can only be distinguished from them by means of the microscope. The rocks are both massive and sheared and are prevailingly dark green or dark greenish grey in colour from the large amount of chlorite which usually appears to be the predominant mineral constituent in hand specimens. They have reached an extreme stage in alteration and under the microscope are seen to consist of a mass of the secondary minerals chlorite, calcite, quartz, epidote, magnetite, and pyrite in which occasionally crystal outlines of former phenocrysts may be seen.

The later group of porphyrites are also much altered, but their discrimination in the field is an easy matter. They are intrusive in the cherts, tuffs, and older porphyrites as dykes and sills. They are dark grey to black in colour and are distinctly porphyritic, with the phenocrysts, originally of pyroxene, weathering out in high relief. Pyroxene, brown hornblende, and plagioclase feldspar were evidently the original essential constituents, but in their present altered state the rocks are largely composed of epidote, calcite, chlorite, magnetite, a little colourless mica, and quartz. In mapping they have been included in the Knob Hill proper. Their age, however, has not been satisfactorily fixed, and, although they have not been found to cut the rocks of the Attwood series in the area, it is yet possible that they may be younger, and may belong to the Phoenix volcanic group of Daly which is referred to Mesozoic age.

Structure.—The whole group is a massive complex in which there is no apparent structure to assist in establishing a stratigraphic sequence. The rocks are much broken by a complicated system of faulting and shearing, but data are absent for the computation of displacements. These planes of weakness run in all directions and at all angles of dip. They are usually filled with gouge and occasionally with quartz and calcite, in places mineralized with pyrite and small amounts of chalcopyrite.

CARBONIFEROUS (?)

ATTWOOD SERIES.

Introduction.—The Attwood series in the Phoenix area admits of a division into two formations which are conformable to one another. The lower or Brooklyn formation consists essentially of limestone or its replaced equivalents, while the upper or Rawhide formation is composed entirely of argillites. Both members are non-fossiliferous and the provisional assignment of the series to the Carboniferous is based on the correlation made by Daly with the Carboniferous series in the Rossland mountains.

BROOKLYN FORMATION.

Distribution.—The Brooklyn formation occupies over half the area of the map, the exposure having a wide semi-circular form, broad to the west, narrowing to the east, and breaking into isolated exposures in its northern extensions. The formation lies on the rocks of the Knob Hill group (General map, section A-A), the basal member of the former being jasperoid in contact with the cherts of the latter.

Lithology.—The formation is susceptible of a three-fold division based on the character and degree of alteration and replacement of the limestone. It consists of (*a*) crystalline limestone with some associated calcareous argillites, (*b*) a zone of jasperoids with some tuffs, argillites, and altered basic intrusives, and (*c*) a mineralized zone composed essentially of garnet and epidote. The latter zone is the most important as in it are contained the large bodies of low grade copper ore.

Limestone.

Distribution.—The limestone had originally a very extensive development, but is now represented by a few isolated exposures, the masses usually resting on a floor of jasperoid rocks. The largest area of limestone occurs in the vicinity of the Brooklyn mine, the other exposures being merely lenses and small masses. Two lenses occur at and just north of the Stemwinder mine. Smaller masses are found on the Snowshoe and Gold Drop claims and underground in the Knob Hill-Ironsides mine, the Snowshoe, and Gold Drop No. 1, where they are included in the mineralized zone, or at the contact between that zone and the jasperoids. The rock, so far as it has been examined, is entirely without fossils.

Lithology.—The limestone is crystalline and massive with a texture varying from extremely fine to medium grained. The colour ranges from pure white to light and dark grey with occasionally a bluish or brownish tinge. All varieties contain more or less quartz and pyrite is rarely absent. The average rock under the microscope is seen to consist of clear and turbid grains of calcite in mosaic arrangement. Evidences of strain and pressure are usually present and are shown by curved twinning and cleavage planes and uneven extinctions. Aggregates of microcrystalline and chalcedonic quartz are of frequent occurrence and are developed interstitially to the grains of calcite or tend to replace the calcite along cleavage planes. Pyrite in minute grains and well formed crystals occurs both in the calcite and quartz.

Chemical Composition.—The two following analyses of typical limestone were made by Mr. F. G. Wait of the Mines Branch.

	I.	II.
$CaCO_3$	90·41	98·40
$FeCO_3$	0·16	0·31
$MgCO_3$	tr.	tr.
Insoluble chiefly silica...	10·00	1·50
	100·57	100·21

I. Brooklyn mine.

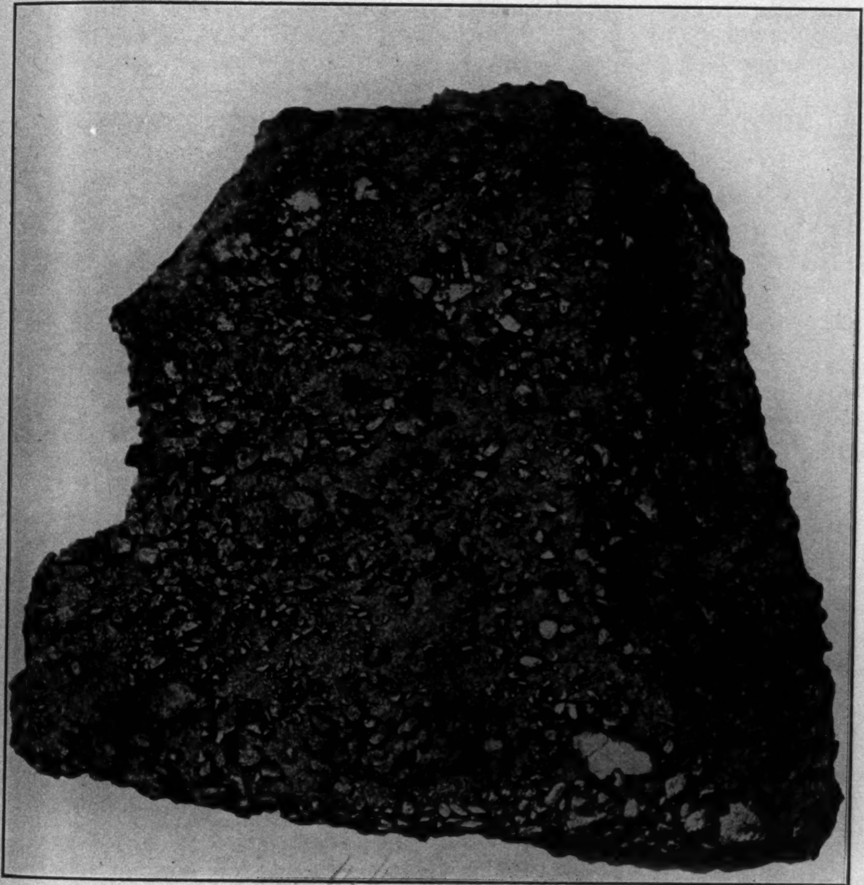
II. Knob Hill-Ironsides mine, 300 foot level.

Structure.—In its alteration to the crystalline form the original bedding planes of the limestone have become in great part obliterated and now only appear in traces. Jointing is a well marked feature in the vicinity of the Brooklyn mine where the strike is northerly and the dip 60° to 85° east, coinciding with the trend of the Brooklyn ore body. In minor masses jointing and fracture planes are intricately associated and the massive limestone gradually passes into brecciated types. Faulting in the limestone with small displacements is probably quite common, but usually data for their discrimination is very obscure or entirely lacking. A complicated faulting, with shearing and brecciation, has probably been an important factor in assisting the processes which have replaced so large a proportion of the original limestone by quartz and lime-silicates.

Zone of Jasperoids.

Distribution.—The jasperoids and associated rocks form in their surface exposure a well marked, widely semi-circular band, occupying the major portion of the western half of the Phoenix

PLATE III.



Limestone replaced in part by silica.

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map and a considerable portion of the eastern half. They lie in all cases directly on the rocks of the Knob Hill group, to which they are, in certain localities, firmly welded by siliceous material. Isolated masses of jasperoid occur well within the limestone (See General map, north of Brooklyn mine).

Lithology.—Jasperoid as defined by Spurr is a 'rock consisting essentially of cryptocrystalline, chalcedonic or phenocrystalline silica which has formed by the replacement of some other material ordinarily calcite or dolomite. The jasperoid may be white or various shades of red, grey, brown, or black, the colours resulting from different forms of iron in varying proportions.'[1]

Included in the zone of jasperoids are the jasperoids proper which are replacements of limestone, as well as other varieties derived from tuffs; argillites, and fragmentary masses of intrusive igneous bodies which were occasionally encountered only in the underground workings.

Macroscopic Character.—The jasperoids consist of oval, rounded, oblong, and sub-angular pebble-like individuals of light grey and white quartz, grey, pink, and brownish cherts, and reddish brown and bright red jasper in a matrix of smaller forms of the same composition with calcite and chlorite. The individuals vary in size from microscopic grains to masses 6 inches or more in diameter. Along the contact of the jasperoids and limestone numerous residual fragments of the latter are included in the former. These occur for several hundred feet on either side from the contact, but with a noticeable diminution of the limestone fragments, as the distance from the contact increases. In the field the rock often simulates in appearance that of a breccia or conglomerate. A banding is occasionally noticeable with the rounded cherty individuals in an alignment which coincides in direction with the major jointing of the adjacent limestone. The rock usually weathers light grey and the rounded individuals stand out in relief as a result of the dissolving out of the calcite matrix.

In the field all transitional forms are to be seen between crystalline limestone on the one hand and typical jasperoid on the other. The replacement takes place along bedding, joint, and fracture planes, the jasperoid growing in bands and tongue-like extensions which increase by coalescing. The replacement also goes on in a more uniform manner throughout the whole mass in the case of some limestone bodies, where the siliceous solutions have followed the finer and almost microscopic planes of parting. In such stages the rock has the appearance shown in Plate III, the pebble-like bodies standing out in high relief on weathered surfaces.

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[1] J. E. Spurr, Geology of the Aspen Mining District. Monograph 31, p. 219, U. S. Geol. Sur.

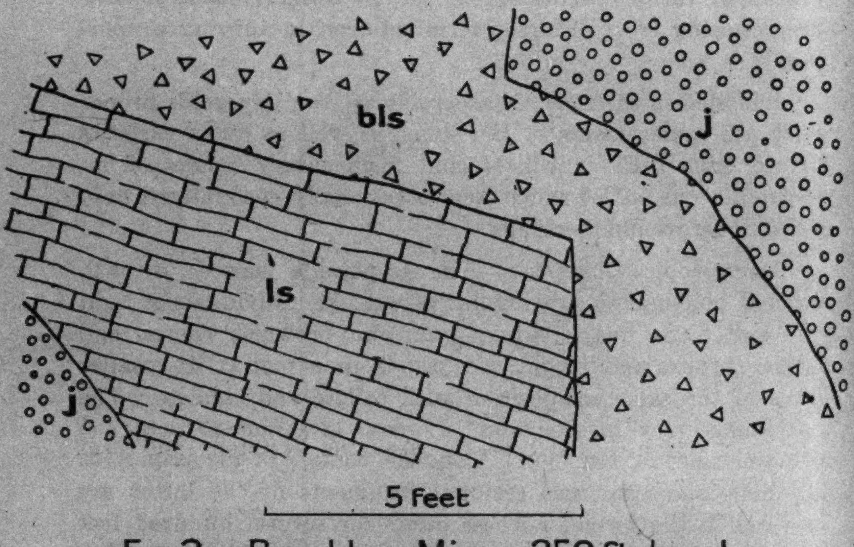

FIG. 2.—Brooklyn Mine, 250 Ft. level Showing jasperoid (j), brecciated limestone (bls) and massive limestone (ls).

The relation of the limestone to the jasperoid is further shown in the accompanying figure (Fig. 2), where the replacement follows the zone of brecciation in the former rock. On the lower side of the massive limestone the jasperoid is in rather sharp contact having replaced the brecciated portion.

Microscopic Character.—Under the microscope the jasperoid is seen to be composed of oval, rounded, oblong, and sub-angular aggregates of cryptocrystalline or chalcedonic and microcrystalline quartz in a matrix of calcite with some granular mosaics of quartz, and small amounts of pale green chlorite and tufts of a colourless mica (sericite?). The calcite is the predominant mineral in the matrix and may represent part of the original limestone which has been redeposited. The siliceous aggregates are oval, rounded, oblong, or sub-angular individuals with smooth and crenulate borders. Some show tongue-like extensions indicating directions of growth and these occasionally form connecting links between two individuals giving irregular and rude dumb bell forms (Plate III). A few aggregates hold small granular clusters of calcite grains as inclusions. In some slides quartz crystals of good form have developed freely in the calcite portion of the matrix. Pyrite is a secondary constituent of usually some prominence, especially in the rock adjacent to the ore bodies. Jasperoids, which were originally medium grained tuffs, possibly more or less calcareous, show in addition to the above mineral constituents, grains and phenocrysts of plagioclase feldspar a few of which show evidences of secondary growth, and fragments of porphyrites, porphyries, aplites, and effusive types of igneous rocks with a partially altered glassy base. Minute faulting of two or more periods is common in the jasperoids: the displacements never exceed 0·1 mm and the planes are filled by veinlets of quartz and calcite.

In the transitional types between the limestone and jasperoid the replacement of calcite by silica follows cleavage and contact planes of the calcite grains, the minute grains of quartz occurring as solitary grains or in clusters in the first stage. From this stage all types showing gradual progression towards the typical jasperoid may be seen.

Origin of Jasperoids and Cherts.

The siliceous rocks of the Brooklyn formation and the Knob Hill group (jasperoids and cherts), probably have a common origin as regards the source of the silica. It would appear that the source was a deep seated one, and that the siliceous solutions may have been derived from the main granodiorite batholith during its early stages of invasion. The limestone wherever an examination could be made is seen to pass downward into jasperoid, and from the relations of the two, both on the surface and in the underground workings, the conclusion appears evident that the siliceous solutions were ascending, and no doubt followed the more favourable zones of faulting and brecciation in the original limestone. (Fig. 18, p. 99). The massive limestone appears to be less readily attacked on an extensive scale, and in it the chemical action progressed more slowly along cleavage and minor planes of fracture. The probable porous character of the ash rocks of the Knob Hill group, presented more favourable conditions for an even and widespread silicification, which accounts for the great thickness of cherts.

Tuffs and Argillites.

Lithology.—The tuffs and argillites are so intimately related to the jasperoids and pass so insensibly into them that they have been included in that zone. The tuffs are fine grained greenish grey rocks some of which have preserved traces of original bedding or banding and probably have occurred as interbeds in the limestone. They are essentially quartz and quartz feldspar tuffs and usually show partial replacements tending towards the jasperoid type. The chalcedonic quartz forms around nuclei of original quartz and feldspar grains.

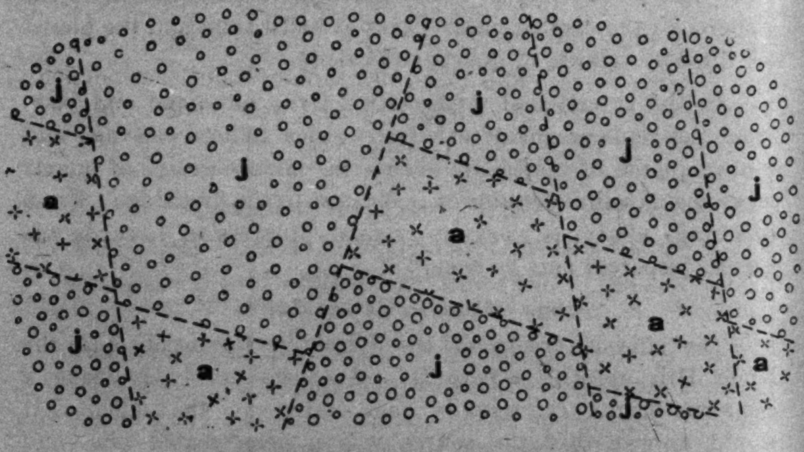

FIG. 3-Diagrammatic sketch showing block faulting of jasperoids (j) and argillite (a).

The argillites were noted chiefly in the underground workings. They appear to pass insensibly into jasperoid at times, while at others the contact is sharp and marked by a gouge filled plane. The blocky occurrence as a whole, however, is distinctive and suggests faulting between the two rocks (Fig. 3, p. 38, and Fig. 7, p. 68), of the character indicated in the accompanying figure.

They are extremely fine grained greenish grey rocks, occasionally banded but usually massive. Some types are reddish brown in colour from the alteration of finely disseminated pyrite to limonite. It is quite possible that part of the argillite may be extremely fine grained tuffs or may have been originally derived from such rocks by the sorting action of water. They are brittle, with a sharp conchoidal fracture, and a fine system of jointing causes the rock to break up into small rhomboidal fragments. These numerous planes are filled with calcite and a little pyrite though the latter is not invariably present.

Microscopically they are seen to be composed of shreds of kaolin, with some microcrystalline and cryptocrystalline grains of quartz, and a little chlorite. Throughout the rock are areas of turbid calcite up to 0·75 mm. in diameter which are sponge-like and hold minute inclusions of the other constituents. Pyrite is present in well formed minute crystals and the slides are traversed by veinlets of clear calcite of three generations.

Composition.—Two rough determinations of that portion of the rocks insoluble in hydrochloric acid were made by Mr. F. G. Wait of the Mines Branch. These gave respectively 56·11 and 63·35 per cent of silica, and 26·38 and 20·78 per cent of alumina, which show the essentially argillaceous character of the rocks. They probably represent the more impervious portions of the original rocks of the Brooklyn formation which resisted the action of the processes of silicification, that so extensively affected the more soluble limestones and porous tuffs.

Igneous Rocks.

Certain types of porphyrites which are associated with the jasperoids and included with them have been exposed in the underground workings of the several mines. They occur, as a result of faulting and shearing, in detached blocks and lens-like masses. They probably occurred as dykes and sills contemporaneous with the tuffs of the Brooklyn formation, or they may belong to the same period as some of the earlier porphyrites of the Knob Hill group. They are highly altered and in hand specimens are usually sheared, rarely massive, dark green in colour, and essentially chloritic in composition. Microscopically they consist of chlorite, epidote, calcite, quartz, magnetite, and pyrite. In this granular mass of secondary minerals an occasional form of an original phenocryst may be discerned.

The Mineralized Zone.

The mineralized zone occurs in interrupted or isolated areas lying in trough-like basins with jasperoid or limestone as the floor. It is essentially a replacement of limestone by epidote, garnet, etc., in a zone of contact metamorphism in which occur all the low grade ore bodies at Phoenix. Owing to its association with the ore bodies this zone forms one of the main subjects for treatment in the chapter on economic geology to which the reader is referred for detailed descriptions here omitted to avoid needless repetition.

RAWHIDE FORMATION.

Distribution.—The Rawhide formation has only a limited exposure in the southeast corner of the Phoenix area and overlies conformably the Brooklyn formation, here locally represented by the zone of jasperoids. The exposure is an erosion remnant of a formerly more extensive development and has a maximum thickness of rather less than 100 feet.

Lithology and Structure.—The formation consists wholly of dark grey to black slightly carbonaceous argillites in beds varying from 3 to 18 inches in thickness. A fine lamination parallel to the bedding planes occurs in some beds, the laminæ being alternately light and dark grey. At the contact with later intrusive dykes of augite porphyrite a narrow marginal zone of the argillite is partially altered to hornstone. Some of the basal beds have been replaced, locally, along the structural planes by jasperoid in narrow tongues and lenses. The beds are either almost horizontal or dip at low angles to the northeast.

The two principal sets of joint planes are almost vertical and strike N. 60° E. and N. 15° W., respectively. These combined with minor planes cause the argillite to break into rhomboidal blocks. Shear zones similar to those in the lower formations occur in all directions and with varying angles of dip. They are filled with gouge from crushed and decomposed rock.

MESOZOIC.

JURASSIC (?).

Igneous Rocks.

Distribution.—A small mass of augite syenite in the northeast portion of the area, and three dykes of syenite porphyry, two of which occur on the Snowshoe claim and one underground in the Rawhide mine, are the only representatives of the granodiorite batholith in the Phoenix camp. They are referred to the Jurassic period from their lithological similarity to dykes and apophyses occurring elsewhere in the district, which are directly connected with the main batholithic intrusions. At Phoenix these intrusives cut the rocks of the Knob Hill group and the Brooklyn formation.

The granodiorite batholith is extensively developed throughout the Boundary district and probably underlies the Phoenix area at no great depth. The rock usually occurs in irregular masses, bosses, and dykes, and in its typical development is a light grey granitoid rock, which varies mineralogically from a granite to a quartz diorite, with hornblende or biotite or both as the chief ferro-magnesian constituents. More basic types of the same intrusion include hornblende gabbro.

Lithology.—The augite syenite is a dark grey granitoid rock of medium grain, consisting of dark grey feldspar and black pyroxene. The rock is very extensively sheared and fractured, the planes being filled with calcite, slightly tinged by yellowish limonite. It weathers to a rusty brown. Microscopically it consists of individuals of orthoclase and plagioclase feldspar, pale yellow augite, brown biotite, quartz, and magnetite with secondary chlorite, limonite, and calcite. The feldspar is too turbid for determination beyond recognizing both the potash and soda-lime types and perthitic intergrowths of the two. The augite is also largely altered to the secondary products chlorite, limonite, and calcite.

The syenite porphyry dykes are not over 12 feet wide and only traceable for a short distance along their strike. In the hand specimens the rock is pink when fresh, weathering to a light brownish grey with a rather vague porphyritic texture. The dykes have been much sheared and fractured, with calcite filling in the planes. Under the microscope the rock is seen to be composed of very turbid orthoclase and plagioclase in small tabular and lath shaped forms. The bisilicate has disappeared, its form remaining and filled with an aggregate of chlorite, limonite, carbonates, magnetite, and quartz. The base is almost cryptocrystalline and consists of an aggregate of quartz and feldspar through which are sponge-like areas of turbid calcite. Numerous minute planes traverse the rock, which are filled with calcite and quartz either together or alone.

TERTIARY.

OLIGOCENE.

Kettle River Formation.

Distribution.—The Kettle River formation is exposed at Phoenix as a relatively narrow band in the central portion of the map. The exposure is about one mile long with a width varying from 40 to 960 feet. Along the western margin of the outcrop the formation overlies the mineral zone of the Brooklyn formation and possibly over small areas the Knob Hill group. To the east it is covered in part by the lavas of the Midway Volcanic group (General map, section A-A).

Lithology and Structure.—The formation consists of conglomerates, feldspathic sandstones, and compact cherty shales of which some are carbonaceous. The trend of the strike is northerly and the dips are prevailingly to the east and vary from 10° to 60°, the average dip being about 35°. The maximum thickness of the formation as determined from logs of diamond drill holes is about 260 feet. A fine jointing perpendicular to the bedding is general with slight shearing along some of the planes, in which pyrite has subsequently been deposited. No evidences of faulting, so common elsewhere, were noted in this isolated exposure, though faults may occur in the portion overlain by the lavas of the Midway Volcanic group.

The massive conglomerates are light grey in colour, containing pebbles of the rocks of the Knob Hill group, and numerous others of a grey quartz porphyry which intrusive rocks has not been found in situ in the vicinity of Phoenix. The pebbles range in size from a fraction of an inch to 5 inches in diameter and are usually fairly well rounded. The matrix is largely feldspathic with subordinate quartz. The feldspathic sandstones, in part massive, are connected with the conglomerates by gradual transitions. They are composed of angular and rounded grains of the feldspars with quartz and bleached biotite in a matrix of the same minerals together with kaolin, calcite, and limonite. The lower beds are rather coarse but pass upwards into finer grained types and finally into the shale horizon.

The shales are compact, some beds being finely laminated, and are usually cherty, especially the darker types. The colour ranges from a dark grey to greenish grey, the latter weathering almost white. The darker beds, in a few places, contain fragments of plant remains which have been altered to lignite with partial loss of original structure. The light coloured beds are very fine grained, and under the microscope are seen to consist of minute grains of quartz, shreds of kaolin, chlorite, limonite, and spicules of partially bleached hornblende; they represent the consolidation of an extremely fine clay. The shales and to a certain extent the sandstones, have been replaced in a slight degree by chert, along the planes of bedding and jointing. No definitely determined ash rocks were found in this exposure although they occur elsewhere in the Boundary district.

Origin and Age.—The formation is the result of lake and river sedimentation, the deposits occurring in the valleys and basins formed during the period of erosion of the early Tertiary. At Phoenix the evenly bedded character of the rocks above the conglomerate horizon, the absence of false bedding, and the fine-grained character of the upper portion of the formation, indicate that deposition took place in quiet waters, possibly along the outer margin of a delta. Subsequent erosion, however, has destroyed the original basin and nothing is known of its local extent and importance. The material, however, is in great part foreign to the vicinity of Phoenix and was transported from other localities, the situation of which has not yet been determined. From plant remains found in similar rocks to the west of Phoenix, the formation can be referred with certainty to the Oligocene period[1] and may be equivalent to the Coldwater group of Dawson in the Kamloops area.

MIOCENE (?)

MIDWAY VOLCANIC GROUP.

Distribution.—The lava flows of the Miocene (?) period probably covered the greater part of the Boundary district, but have been separated into isolated areas by subsequent erosion. The exposure at Phoenix parallels that of the Kettle River formation and lies above and to the east of it. The lavas also overlie parts of the Knob Hill group and Brooklyn formation, and also have been found to occur in lateral sheets within the Kettle River formation injected along planes of bedding.

The exposure has a length of a little over a mile and varies in width from 1,100 to 2,000 feet. To the south of the Canadian Pacific railway, the lava is inconspicuous as a topographic feature, but to the north along Deadman ridge it presents steep slopes with slight escarpments on both east and west flanks. The thickness compiled from the logs of diamond drill holes varies from a few inches to 200 feet, and is probably over 300 feet on parts of Deadman ridge.

Augite Trachyte.

Lithology.—The rocks of the group range in composition from basalt to trachyte, though at Phoenix, the rock so far as determined is an augite trachyte or a closely related type. Vesicular and amygdaloidal types occur locally but are not common. The cavities are from 0·25 to 0·4 of an inch in length and are of irregular oval or dumb-bell form, filled with concentric layers of calcite, chlorite, limonite, and quartz, the former mineral being on the outer zone and the latter occupying the centre. A rude flow structure is apparent in the amygdaloidal types. The texture is porphyritic, the phenocrysts being embedded in a finely crystalline or dense glassy base. The colour ranges from light brownish grey to almost black, the phenocrysts of feldspar being light grey to almost white. The types of rock at Phoenix all appear to be of the one flow, the main difference being one of texture.

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[1] Penhallow, D. P. A Report on the Fossil Plants from the International Boundary Survey for 1903-1905, collected by R. A. Daly. Trans. Roy. Soc. Can., Third series, Vol. I, 1907, pp. 318-327.

The principal type and the most widely exposed as well as the freshest, is a light brownish grey porphyritic rock with white weathering phenocrysts of feldspar, dark pyroxenes, and plates of brown biotite in a fine microcrystalline base, which contains noticeable grains of pyrite.

Microscopic Characters.—Both orthoclase and soda-orthoclase are present in phenocrysts and individuals up to 2·5 mm. in length. They all show the effects of corrosion and of later growth, giving a crenulated border to most. The plagioclase is andesine and the phenocrysts are usually surrounded by a shell of orthoclase. They are finely twinned according to the albite law only. The feldspar is fresh with but slight incipient kaolinization along the cleavage planes and irregular cracks. Slight strain shadows are general.

The augite individuals vary from 0·5 to 1·5 mm. in length and show a slight approach to idiomorphic form. The mineral is pale yellow; most of the individuals show slight alteration to chlorite along irregular cracks, while a few are completely altered to chlorite, calcite, and magnetite. A few oblong brown biotites from 0·4 to 0·8 mm. in length occur and have as inclusions closely crowded grains of magnetite which have developed along the planes of cleavage. Larger grains of magnetite up to 0·5 mm. in diameter are generally surrounded by a narrow rim of biotite.

The base consists of laths of orthoclase and plagioclase feldspar, rounded idiomorphic individuals of pale green augite, and irregular plates of biotite occupying angular interspaces between the feldspars. The augite and biotite are but slightly altered to chlorite. Magnetite, no doubt titaniferous, is in rather large amount, mainly as inclusions in the coloured constituents. Apatite occurs in small amount as stout hexagonal and slender prismatic forms. Calcite is in rather large amount as patches in the feldspar and as a filling of fracture planes in the larger individuals of feldspar and augite. It has probably in great part been introduced into the rock by circulating waters and deposited. No free silica of primary origin was noted in any of the slides.

Chemical Analyses.—An analysis of this rock was made by

Mr. M. F. Connor of the Mines Branch. It is given under column I. Column II contains the analysis of an augite trachyte from Bauza, Columbretes islands, Spain, analysed by R. Pfohl.[1]

	I.	II.
SiO_2	52·64	33·12
Al_2O_3	20·69	20·48
Fe_2O_3	2·54	5·13
FeO	1·82	1·50
MgO	1·61	1·88
CaO	3·93	4·29
Na_2O	4·84	6·20
K_2O	5·99	4·88
H_2O +	2·23	2·25
H_2O –	0·28	——
CO_2	0·75	——
TiO_2	0·64	0·25
P_2O_5	0·41	0·43
MnO	0·07	——
SrO	0·21	——
BaO	0·60	——
	99·25	100·59

The augite trachyte at Phoenix is closely related chemically to an intrusive rhomb porphyry of probably the same period, which occurs west of Phoenix near Rock creek. The description of the rock has not been published, but will appear in the report of R. A. Daly[2].

According to the quantitative classification of igneous rocks the calculation of the norm places the augite trachyte in class Persalane, order Russare, rang Viezzenase, subrang Procenose.

Structure.—The lava exposed at Phoenix shows no evidence of faulting with displacement, though, as criteria for its detection are absent, there may have been such faulting. Jointing in several directions is a prominent feature, causing the rock to break up into irregular angular blocks. Basaltic jointing is rare, and was seen only in a rock cut on the Brooklyn spur near the Canadian Pacific Railway station. In contact with the underlying rocks a foot or so of the lava is brecciated and in this zone are fragments of the floor rocks which have been caught up and cemented with the lava breccia by more fluid portions of the flow.

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[1] Washington, H. S. Chemical Analyses of Igneous Rocks. U. S. G. S. Prof. Paper, No. 14, pp. 262-63.

[2] Geology of the North American Cordillera at the Forty-Ninth Parallel. (To be published by the Boundary Commission).

Age of Lava.—A period of erosion intervened between the deposition of the Kettle River formation and the lava flows, and the former was in great part removed during this interval. The lava is, therefore, unconformable to the Kettle River formation, and has been referred to the Miocene period. It may be contemporaneous in age with Dawson's Volcanic group in the Kamloops area[1].

AUGITE PORPHYRITE.

Distribution and Occurrence.—The augite porphyrite occurs in dykes, sills, and stocks and is intrusive in all the older formations, including the lava flows. Exposures are general throughout the map area but have their greatest development in the northern half. When traced underground, they are found to follow very irregular courses and vary greatly in attitude, with sharp changes from vertical to almost horizontal (Fig. 6, p. 61). The rock has an irregular system of jointing which occasionally develops normal to the border of the body. Faulting with actual displacement was only noted in one instance.

Lithology.

Macroscopic Character.—The rock, when fresh, is dark grey in colour and consists of phenocrysts of dark grey feldspar, dark brown to black pyroxene and hornblende and black biotite in a fine grained base composed of the above minerals. The rock weathers to a light grey with a brownish tinge, the feldspars becoming dead white. Finer grained varieties decompose readily to a rusty sand. The dykes cutting the ore bodies are in part much altered, with a development of pyrite and calcite which locally form small veins in shear planes parallel to dyke walls. The pyrite is prominent in its occurrence as feathery branching aggregates distributed through the calcite. The borders of the dykes present dense porphyritic selvages with dull pitchy lustre.

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[1] Dawson, G. M. Geological Record of the Rocky Mountain System in Canada. Bull. Geol. Soc. Amer., Vol. 12, pp. 80-82.

They are composed of calcite-chlorite aggregates from the alteration of augite in a base partly crystalline and partly dark brown glass.

Microscopic Character.—In the typical rock the feldspar phenocrysts occur either singly or in clusters of large and small tabular, lath-shaped and square forms and irregular individuals with smooth or interlocking borders. The terminal faces are rarely clear cut but are generally jagged or crenulate, indicating incomplete growth of the phenocrysts. The plagioclase is predominant over orthoclase in the larger phenocrysts, and the former is on the line between andesine and labradorite. It is twinned according to the albite law, occasionally combined with Carlsbad twinning and more rarely with pericline twinning. Some individuals show bent and broken twin planes, the latter being slightly faulted. A few are partially surrounded by a rim of orthoclase. The feldspar, on the whole, is fresh with only slight alteration along cleavage and fracture planes. A few individuals, however, are almost completely altered to turbid aggregates of kaolin and carbonates. The augite is pale yellow and occurs in sharp and rounded forms and as irregular individuals up to 3 mm. by 1·5 mm. in size. Some show corroded borders now surrounded by a rim of biotite or its alteration product, chlorite. The larger individuals are fresh, but many of the smaller ones are altered to chlorite, turbid carbonates, and magnetite.

Biotite and brown hornblende alternate in different exposures of the porphyrite and have much the same mode of occurrence. The biotite is in relatively larger amount than the hornblende, but occurs mainly as small oblong forms and irregular plates throughout the base and as inclusions in the plagioclase and augite arranged parallel to the twinning and cleavage planes respectively. The base is microcrystalline in great part and largely feldspathic. Quartz in small amount, magnetite, and apatite complete the list of minerals.

Chemical Analyses.—An analysis of the augite porphyrite by M. F. Connor of the Mines Branch gave the results placed under column I. For comparison, under column II is placed an analysis by W. Hampe of a quartz augite diorite from Lampersdorf, Silesia.[1] Column III gives the results of an average of 20 quartz diorites.[2]

	I.	II.	III.
SiO_2	55·90	55·54	59·47
Al_2O_3	15·52	15·64	16·52
Fe_2O_3	1·22	1·19	2·63
FeO	5·22	7·13	4·11
MgO	4·70	4·84	3·75
CaO	5·79	5·67	6·24
Na_2O	2·89	3·17	2·98
K_2O	4·45	2·28	1·93
H_2O +	1·40	2·93	1·39
H_2O –	0·60		
CO_2	0·14	0·40	——
TiO_2	0·90	1·24	0·64
P_2O_5	0·46	0·45	0·26
MnO	0·08	——	——
SrO	0·09	——	——
	99·36	100·48	99·92

According to the quantitative classification, the calculation of the norm places the rock in class Dosalane, order Germanare, rang Andase, subrang Shoshonose.

PULASKITE PORPHYRY.

Distribution.—Pulaskite porphyry (alkaline syenite porphyry) occurs in dykes and sills which often pass from one into the other, and gives in these cases, rather irregular outlines to the surface outcrops. The rock is the youngest intrusive in the district and marks the closing period of igneous activity. In the Phoenix area the pulaskite porphyry has not been seen cutting the augite porphyrite, but such relations have been found elsewhere in the Boundary district. In one instance in the Phoenix area (See General map, augite porphyrite stock near south end of the area of Kettle River formation), a dyke of pulaskite porphyry is in contact with augite porphyrite, and shows the characteristic chilled margin. In this case the fissure filled by the pulaskite was interrupted at one point by an extension of the porphyrite stock, which broke the continuity of the dyke.

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[1] Washington, H. S. Chemical Analyses of Igneous Rocks. U. S. G. S. Prof. Paper No. 14, p. 282, No. 87.

[2] Daly, R. A. Average Composition of Igneous Rock Types. Proc. Amer. Acad. of Arts and Sciences, Vol. 45, No. 7, p. 223.

Pulaskite dykes are found generally throughout the map area, and are rather numerous in the underground workings where they are found to increase in number with depth. Earth movements in this area have been slight since this intrusion, and only one case of faulting was noted, in which the throw was less than the width (4 feet) of the dyke.

Lithology.

Macroscopic Character.—The rock, when fresh, is of a grey colour and consists of solitary individuals and segregated clusters of feldspar phenocrysts in a fine grained highly feldspathic base. In the underground mine workings, the rock is less fresh and of a prevailingly greenish cast, due to the development of chlorite. In surface exposures, the body of the rock weathers to a pale reddish brown and the feldspar phenocrysts to a pale brown giving the rock a very characteristic appearance, and presenting a strong contrast with the associated rocks through which it intrudes.

Microscopic Character.—The rock consists essentially of clusters and sparsely scattered phenocrysts of twinned and untwinned feldspar, a few of almost completely altered augite and biotite in a feldspathic base, with additional hornblende, biotite, quartz, magnetite, apatite, and chlorite. The feldspars occur in both tabular and lath shaped forms up to 2·5 mm. in length and 1·75 mm. wide, and present both smooth and interlocking borders to one another. The soda-orthoclase is slightly turbid in the central portion with usually a clear exterior zone. The plagioclase ranges from oligoclase to acid andesine and is finely twinned according to the albite law, a few individuals having, in addition, the Carlsbad twinning. The larger individuals are surrounded by a rim or crust of clear orthoclase which has an irregular crenulated border. The smaller feldspars of the base occur in tiny laths and irregular individuals showing mutual growth interference. Augite and large biotite phenocrysts are few in number, of good form, but are almost wholly altered to granular carbonates with chlorite and magnetite. The biotite of the base is in oblong and irregular forms and is comparatively fresh. Small acicular and allotriomorphic individuals of partially chloritized green hornblende occupy spaces between the feldspars of the base and are present in considerable amount. Quartz and apatite are in trifling amount, the latter occurring as inclusions in the feldspar, the former interstitial to it. Magnetite is the prominent accessory and is present in grains up to 0·4 mm. in diameter. A few of the interstitial spaces are filled with fibrous and platy aggregates of a brightly polarizing secondary mineral which may be an alteration of some feldspathoid, possibly nepheline.

Chemical Analyses.—A chemical analysis of this rock was made by M. F. Connor of the Mines Branch, and appears in column I. For the purpose of comparison an analysis of pulaskite from Rossland by Dr. F. Dittrich, Heidelberg[1], is placed in column II. The third column contains the average of 23 analyses of alkaline syenite.[2]

	I.	II.	III.
SiO_2	57·32	62·59	61·99
Al_2O_3	17·27	17·23	17·93
Fe_2O_3	1·62	1·51	2·22
FeO	3·94	2·02	2·29
MgO	2·68	1·30	0·96
CaO	4·24	1·99	2·55
Na_2O	4·52	5·50	5·54
K_2O	5·96	6·74	4·98
H_2O +	0·47	0·30	0·76
H_2O −	0·08		
TiO_2	0·88	0·54	0·56
P_2O_5	0·51	0·11	0·14
MnO	0·09	tr.	0·08
SrO	0·06	——	——
BaO	0·24	——	——
	99·88	99·83	100·00

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[1] R. W. Brock. "Preliminary Report on the Boundary District," Sum. Rep. Geol. Sur. of Canada, 1902, p. 104 A.

[2] R. A. Daly. "Average Composition of Igneous Rock Types," Proc. Amer. Acad. of Arts and Sciences, Vol. 45, No. 7, p. 220.

The rock is slightly more basic than the average and the Rossland pulaskite and may be considered as a transitional type between pulaskite and monzonite.

From the calculation of the norm the rock is referred to class Dosalane, order Germanare, rang Monzonase, subrang Monzonose of the quantitative classification.

SUMMARY.

The igneous rocks of Tertiary age occurring at Phoenix are closely related both mineralogically and chemically, and are probably differentiates derived from the same magma basin. No published statement regarding the number of lava flows in the Boundary district has yet been made, but it appears that there were several periods of flow, the oldest being olivine basalt, and the youngest some variety of alkaline trachyte to which the augite trachyte at Phoenix is allied. The intermediate flows were andesites and dacites. The pulaskite porphyry is considered the intrusive equivalent of the trachyte, while the augite porphyrite may bear a similar relation to the andesites, though in the latter case no data are to hand to confirm this view.

CHAPTER V.

ECONOMIC GEOLOGY.

Phoenix Mineral Zone.

INTRODUCTION.

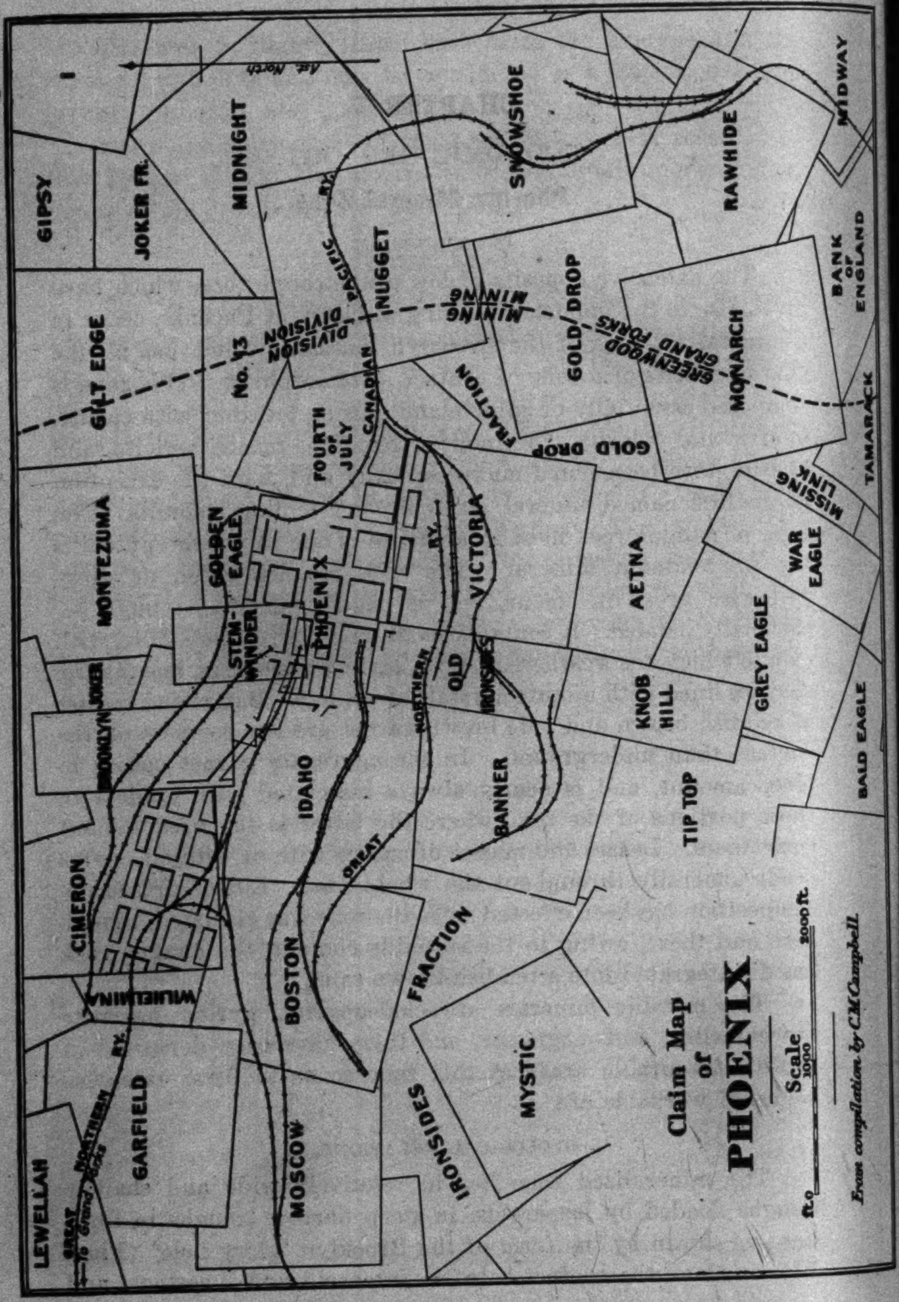
The extensive deposits of low grade copper ore, which have given rise to the important mining industry at Phoenix, occur in a mineralized area of the Brooklyn limestone which has all the characteristics of a zone of contact metamorphism. This zone is composed essentially of epidote and garnet, together with calcite, quartz, and chlorite. Actinolite, tremolite, zoisite, sericite, and apatite have been noted microscopically and, with the exception of the first named mineral, occur in very trifling amounts. The type of gangue rock most in evidence is one in which epidote is the predominant mineral. The rock is dark green or dirty yellowish green in colour, and is usually massive, though occasionally banded. It contains small irregular cavities filled with calcite which has weathered out on surface exposures, leaving the cavities lined with minute crystals of epidote. Bands and masses of reddish brown and pale brown garnet are less common on the surface than underground. In the aggregate garnet occurs in large amount, and is nearly always associated with epidote in those portions of the zone where the latter is the predominant constituent. Lenses and masses of calcite with or without quartz occur generally throughout the whole zone. Little surface decomposition has been effected since the zone was glaciated, though here and there, owing to the sulphide content, the gangue rock has disintegrated into a reddish brown sand.

The metallic minerals are chalcopyrite, pyrite, hematite (specularite), and magnetite, and these have been deposited in certain favourable areas in this zone so as to form extensive bodies of workable ore.

GEOLOGICAL RELATIONS.

The mineralized zone lies in relatively wide and shallow troughs flooded by jasperoids, in steep narrow troughs in limestone as shown by the form of the Brooklyn 'glory hole' (Plate VI), or along the contact between jasperoid and limestone, and

Fig. 4


Claim Map of PHOENIX
Scale
ft. 0
1000
2000 ft.
From compilation by C.M.Campbell
Ast. North
GIPSY
JOKER FR.
MIDNIGHT
SNOWSHOE
RAWHIDE
MIDWAY
GILT EDGE
No. 13
NUGGET
GOLD DROP
MONARCH
BANK OF ENGLAND
FOURTH OF JULY
FRACTION
GOLD DROP
TAMARACK
MISSING LINK
MONTEZUMA
GOLDEN EAGLE
PHOENIX
VICTORIA
AETNA
WAR EAGLE
GREY EAGLE
STEM-WINDER
OLD IRONSIDES
KNOB HILL
BALD EAGLE
JOKER
BROOKLYN
IDAHO
BANNER
TIP TOP
CIMERON
BOSTON
FRACTION
WILHELMINA
GARFIELD
MOSCOW
IRONSIDES
MYSTIC
LEWELLAN
CANADIAN PACIFIC RY.
DIVISION
DIVISION
MINING
MINING
GREENWOOD
GRAND FORKS
GREAT NORTHERN RY.
GREAT
NORTHERN RY.
To Grand Forks

between jasperoid and the quartzose rocks of the Knob Hill group. The zone is considered to have been originally in great part limestone, which has been replaced metasomatically by lime silicates chiefly epidote and garnet.

In part the zone is overlain unconformably by the Kettle River formation, and in part covered by the lava of the Midway Volcanic group (General map, section A-A). Both the zone and the included ore bodies are cut by dykes, sills, and stocks of augite porphyrite and pulaskite porphyry, which intrusive bodies increase in number with depth, as noted in the mine workings. Certain older dykes of basic porphyrites occur in apparently fragmentary masses, but so great has been their alteration, that their origin could only be determined microscopically. In the ore bodies they represent barren areas and were evidently not favourable localities for ore deposition.

Distribution.

This mineralized zone, probably once continuous over an area greater than that now exposed, has been separated by erosion into a number of detached areas, which for convenience have been termed the Granby, Brooklyn, Stemwinder, Gilt Edge, Montezuma, and Gold Drop respectively.

The Granby Zone.—The principal mines with one exception are situated on the Granby zone, which surficially is semi-elliptical or horseshoe shaped (See General map) in form. The west limb is 3,200 feet long and 1,000 feet wide; while the east limb is 2,250 feet long and from 350 to 1,000 feet wide. The curved connexion to the south is 2,000 feet long and from 200 to 700 feet wide. The actual horizontal dimensions, however, are much greater, as a very considerable area is overlain by the sedimentary and igneous rocks of Tertiary age. The thickness of the west limb along an east and west axis varies from 160 to 350 feet with a gradual thinning out to the east (General map, section A-A). Along the north and south axis of the same limb the maximum thickness in the central portion is about 350 feet, and from that point the zone gradually thins out in both directions. The jasperoid floor of the zone is broadly rolling (with local sharp high rolls), and has the form of a double trough or basin with half of the eastern basin lacking (General map, section

A-A). The contact between the mineralized and jasperoid zones is sharp and usually marked by a fissure from a fraction of an inch to 7 feet wide, filled with a gouge of disintegrated jasperoid.

The Brooklyn Zone.—This zone, on which is situated the Brooklyn-Idaho mine, lies to the west of the Granby zone and extends across the valley of Twin creek, crossing the lower town of Phoenix. In its central portion, which coincides with the lowest points in the valley of Twin creek, the zone has suffered considerably from erosion, with the consequent removal of an important part of the original ore body. Along the central portion of the valley it is covered by sands and gravels, and the surface limits have, therefore, been projected from the underground workings.

The zone has an elongated pear-shaped form, broad and shallow to the south, narrowing and becoming steeper to the north until it is enclosed by almost vertical walls of limestone, as shown by those of the Brooklyn 'glory hole' (Plate VI), or of jasperoid to the east, and limestone to the west. The floor is mainly limestone with some jasperoid in the southern part (Fig. 18, p. 99). The length is about 1,850 feet, and the width varies from about 400 feet in the south to less than 50 feet in the extreme north.

Stemwinder Zone.—The Stemwinder zone is a small lenticular body, about 600 feet long and from 8 to 60 feet wide. Its attitude is about vertical, with brecciated limestone forming the east and jasperoid the west wall (General map). In its southern extension it is known to be underlain by jasperoids. One mine only, the Stemwinder, is situated on this zone.

The Montezuma Zone.—This zone occurs on the Montezuma claim and lies on the southern slope of the ridge of the same name. It is cut off to the north by a mass of augite porphyrite. Its south and east boundaries are rather indefinite, as the whole area is very shallow and gradually thins out towards the bordering and underlying jasperoid. It is of no commercial importance.

The Gilt Edge Zone.—The Gilt Edge lies at the head of Deadman gulch and is probably an elongated pear-shaped area. The actual limits, however, are concealed to the north by drift, and the zone is overlain to the east by the rocks of the Kettle River formation, and those of the Midway Volcanic group. To the west it is cut off by an intrusion of augite porphyrite. Its known length is about 950 feet, and its width varies from 20 to 400 feet. No workable deposit of ore has so far been discovered in this area.

The Gold Drop Zone.—The Gold Drop zone is situated in the northeast part of the claim of that name, and is about 150 feet north of the eastward extension of the Granby zone. It lies in a flat shallow basin in the jasperoid with some quartzose limestone, and is partly overlain by the lava of the Midway Volcanic group. It is a little over 300 feet long, about 200 feet broad, and has a maximum thickness of about 50 feet. It contains one ore body known as the Gold Drop No. 1.

Character of the Ore Bodies.

The ore bodies are broadly lenticular in form, and lie in basin shaped troughs in the jasperoid zone and crystalline limestone of the Brooklyn formation. The irregular lenses are either simple or compound, the latter type occurring in the Knob Hill-Ironsides body which is the largest deposit in the camp (Fig. 10, p. 77). The size of the bodies varies from about a hundred feet in length and from 20 to 50 feet wide, to a body like the west lens of the Knob Hill-Ironsides mine which has a length of nearly half a mile, a maximum thickness of 125 feet, and a known maximum width of 900 feet. All the larger bodies bear a distinct relation to the topography, and their dip or pitch approximately coincides with the local slopes of the ridges.

Jasperoid, with occasionaly crystalline limestone, forms the structural foot-wall, which is, as a rule, the commercial foot also, though in limited areas bands of barren gangue from a few inches to a hundred or more feet in thickness separate the pay ore from the structural foot-wall (Fig. 9, p. 76). In some bodies the dip is flat, not exceeding 20 degrees; but generally the dip is high along the outcrop, ranging from 45 to 80 degrees, with a pronounced flattening with depth (Fig. 10, p. 77). The hanging-wall is usually a purely commercial one except in the case of small bodies, and the narrow terminal portions of the main ones (Fig. 9, p. 76). The ore body either gradually becomes of lower and lower grade, or the pay ore terminates suddenly against a gouge filled fissure.

Fissure System.—The ore bodies are traversed by a system of fissures locally termed 'slips.' They run in all directions and at all attitudes from vertical to horizontal. They vary in length from several hundred feet down to almost microscopic dimensions. The latter again pass into still finer fractures, in and between individual grains of the gangue minerals. The main fissures are approximately parallel to the foot-wall of the ore body in which they occur (Fig. 8, p. 75), and vary from a few inches to 7 feet in width and are usually filled with gouge. Many pass into the country rock below the foot-wall, as well as upwards and outwards into the zones of barren gangue rock adjacent to the ore bodies.

The fissures are not all of the same age, but belong to three or more generations. They are tension fractures in the main and have probably been caused by unequal stresses set up in the zone of mineralization during the period of replacement of the limestone. It is possible that the more important were formed during a period of fissuring in the country rocks at the time of the intrusion of the granodiorite batholith.

The fissures have undoubtedly been the important factor in the deposition of the ore, forming as they did channels for the ore bearing solutions, the movement of which may be compared to the movement of the sap in a tree passing from roots to trunk, then through the many subdivisions of the branches until the leaves are finally reached. In the case of the ore bodies, the main fissures are the trunk channels which connect with the smaller fissures, terminating in the microscopic fractures of the individual mineral grains. The ore solutions following these courses, were, therefore, able to deposit their metallic contents in a very uniform and widespread manner. Many of the fissures, however, either wholly or in part filled with gouge and rendered more or less impervious, played an important part by guiding and deflecting the ore solutions, and thus promoting a better concentration of their metallic contents. In the closing periods of ore deposition a large number of the fissures were filled with calcite, quartz, and chlorite, with or without the metallic minerals. Portions of some of the larger fissures remained open and permitted free development of large druses of calcite (Plate IV A).

The fissuring may have been accompanied by extensive faulting but the actual displacements if any, in most cases, have been concealed by the homogeneous character of the gangue rock and ore bodies. Evidences of late movement are furnished by numerous slickensided surfaces occurring along many of the smaller fissures, and in two cases prominent faults occur in the ore bodies, one in the Knob Hill-Ironsides and one in the Snowshoe (Figs. 10, 11, and 16). This faulting occurred subsequent to the formation of the ore bodies and is probably of the same age as the fault system of the Midway Volcanic group.

Irregular wedge shaped masses or ribs of almost barren gangue rock occur in all the ore bodies, and are of varying importance as obstacles in mining. Along parts of the main ore bodies, and in some of the smaller bodies, the continuity is

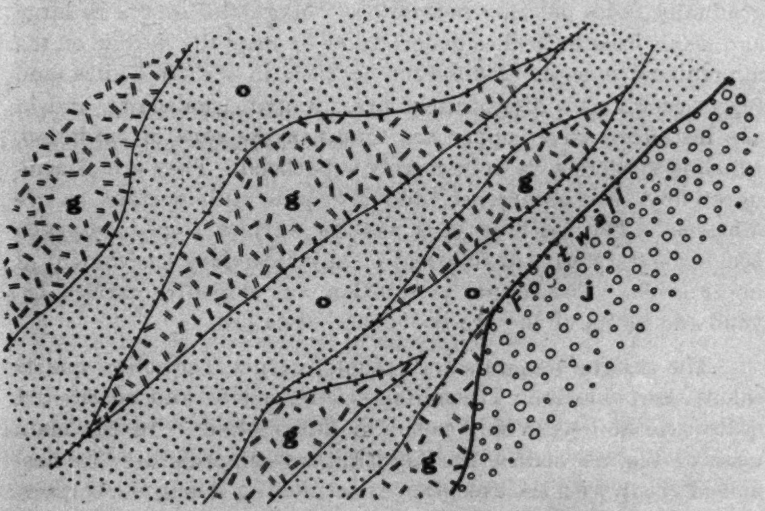


Fig. 5-Diagrammatic sketch showing general relations of ore (o) and lightly mineralized or barren gangue (g).

broken and the ore occurs in wedges or ribs, separated from one another by complementary ribs or barren gangue or 'waste' (Fig. 5, p. 59).

The boundaries are fissure planes of varying width, filled with quartz and calcite or simply with gouge. Depending on the relative amount of ore and barren gangue, these bodies are stoped out or left standing; as the ore is so uniformly low grade, much admixture of barren gangue would bring it below the shipping grade.

Character of the Ore.

The average ore is almost self-fluxing in character and of such a grade that the average copper content ranges from 1·2 to 1·6 per cent. The metallic minerals are chalcopyrite, pyrite, and specular hematite which are uniformly though sparsely distributed through the gangue minerals, along fractures and cleavage planes, and interstitially between individual grains. It is generally found that the ore adjacent to the fissures is of slightly higher grade than the average, but gradually fades out into normal ore. Magnetite occurs in large and small isolated bodies generally at or near the border of the mineralized zone, or at different horizons in the ore bodies, and rarely occurs as a disseminated ore. Azurite, malachite, and in one instance native copper are found in the zone of oxidation, which is so shallow as to be merely superficial. They are of comparatively rare occurrence, and are quite unimportant as ore minerals. The leaching of a shallow surface zone by oxygen bearing waters was not followed by any secondary enrichment at lower levels. The copper in solution was evidently carried beyond the limits of the ore bodies and thus lost.

The gangue minerals are epidote, garnet, actinolite, quartz calcite, and chlorite. Tremolite, sericite, zoisite, and apatite are quite rare and were only noted in thin sections. In the main mass of the ore bodies, the predominant minerals are the first named group with the exception of actinolite. Along the borders, where the walls are limestone, the gangue is composed essentially of quartz and calcite which directly replaces the limestone, accompanied by the deposition of the chalcopyrite and other metallic minerals (Figs. 6, p. 61).

Banded ores occur adjacent to the limestone as in the north end of the Brooklyn mine, and also where no limestone now exists, as on the surface along the northern portion of the Knob Hill-

Ironsides body. Underground the banding varies in distinctness and is somewhat indefinite. It may represent structural planes in the original rock prior to its replacement. The banding, however, is only of local occurrence, the massive type of ore predominating throughout.

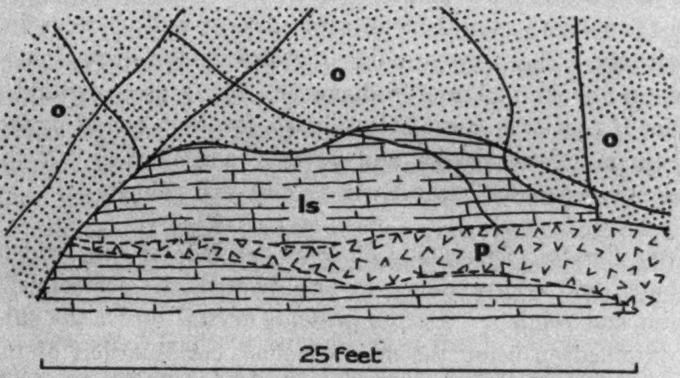


FIG. 6.-Knob Hill-Ironsides Mine, 300 ft. level. Limestone (**ls**), ore (**o**) and quartz augite porphyrite (**p**). Ore replacing limestone.

MINERALOGY.

Under this heading only the minerals associated with and composing the mineralized zone, and the ore bodies will be considered.

METALLIC MINERALS.

Native.

Copper.—Native copper occurs on the Gilt Edge claim as minute scales and arborescent plates along fracture planes in the gangue rocks. It is secondary, and has probably been reduced from copper bearing solutions by the action of organic acids.

SULPHIDES.

Chalcopyrite (Sulphide of copper and iron).—Chalcopyrite is the most important and valuable metallic mineral and contains not only all the copper, but the gold and silver values as well. It occurs as narrow veinlets and threads filling minute cracks, fractures, and cleavage planes, in epidote, garnet, calcite, and quartz, and as grains and branching aggregates developed interstitially to individuals of the gangue minerals or at points where several fracture planes intersect. In the magnetite it fills in the spaces in the skeleton octahedra, as well as occurring interstitially. The more prominent grains in the disseminated ore average about 1·25 mm. in diameter. Many are surrounded by a rim of hematite (specularite), and a few by a rim of pyrite. It occurs in larger masses, and pockets, and in many of the fissures is interbanded with quartz, calcite, and chlorite.

Iron Pyrites (Disulphide of iron).—Pyrite is very widely distributed and occurs almost invariably with the chalcopyrite as grains and veinlets. It often presents crystal forms, the cube and pyritohedron being the most common, combinations of the cube and octahedron being comparatively rare. The crystals often form in series arranged in clusters or in lines. In the ore bodies near the foot-wall, pyrite occurs in a few instances as small lenses a few feet long and from 1 to 4 inches wide, composed of a granular mass of crystals and grains. It has a wide range in time of deposition occurring both prior to the chalcopyrite, and as the last of all the minerals to crystallize, being found developed on the faces of calcite crystals in druses formed in some of the more open fissures. The pyrite as a rule carries no values whatever either in copper, gold, or silver.

Pyrrhotite (Magnetic iron pyrites).—Pyrrhotite is very sparingly distributed and was only noted on two occasions, when it occurred as minute grains in altered porphyrite which was associated with the ore body.

Oxides.

Hematite (Sesquioxide of iron).—The hematite occurs as the variety specularite; it is associated intimately with the sulphides, and was deposited at the same time as the chalcopyrite. It forms in grains and plates, often arranged in rosette or radiate clusters. It occurs in minute plates or scales along cleavage planes in calcite, along fracture planes in quartz, and as veinlets in the ore body which are faulted and cut by later ones of calcite.

It has practically the same range as the chalcopyrite, and is found in many of the veins filling fissures.

Magnetite (Magnetic oxide of iron).—Magnetite occurs in bodies and masses of considerable size near the foot-wall of some of the ore bodies. On the Monarch it forms by itself a very extensive ore body. It also occurs sparingly and irregularly as smaller lenses and masses in nearly all the ore bodies. It varies from fine to medium grain, and the polished surface shows the granular aggregates to be made up of a series of skeleton octahedra, with the interspaces filled by chalcopyrite, pyrite, quartz, and calcite. It is apparently earlier than the chalcopyrite, and is probably in great part contemporaneous with the lime-silicates. The magnetite of itself contains no values beyond its iron content.

Limonite (Hydrous sesquioxide of iron).—Limonite, in light yellow or brown colours, is found as streaks or irregular and narrow bands in certain fissures which have been channels for surface waters. It is derived from the sulphides by oxidation, and occasionally occurs in soft incoherent crystals after pyrite.

Carbonates.

Azurite (Blue copper carbonate).—Azurite, with deep blue colour and rather dull lustre, occurs with limonite in the surface zone of the ore bodies. It forms incrustations on the chalcopyrite with botryoidal and finely stalactitic surfaces.

Malachite (Green copper carbonate).—Malachite, of pale green colour and earthy lustre, occurs with the azurite and has similar associations.

NON-METALLIC MINERALS.

Silicates.

Epidote (Lime-iron—aluminium silicate).—Epidote is the most prominent individual constituent of the gangue minerals. It is rarely found in bands or masses of any size by itself, but is usually associated with calcite, quartz, and chlorite, with or without garnet. It occurs in mosaics of polygonal and rounded grains traversed by fine fractures which are filled with the metallic minerals. Towards the calcite it presents good crystal forms up to 0·1 mm. in length. The crystals are dark green and olive green with brilliant lustre, and are often found in clusters embedded in calcite. Twinned individuals are comparatively rare.

Sheared portions of the massive epidote show slight alteration to chlorite. Zoisite the lime-epidote was only noted microscopically in a couple of instances, occurring in minute colourless crystals.

Garnet (Lime-iron silicate).—The garnet occurs generally through the mineralized zone and quite often in rather pure bands and masses. The colour varies from reddish, greenish, and pale brown with rather dull lustre, to more brilliant wine coloured crystals. It is probably essentially andradite, with possibly some admixture of the grossularite (lime-aluminium silicate) molecule, as indicated from partial analyses of types of the garnet gangue. It occurs in mosaics of rounded grains and polygonal forms, and also as distinct crystals varying in size up to 0·4 inches in diameter. The usual forms are the rhombic dodecahedron and combinations of it with the tetragonal trisoctahedron.

Microscopically the garnet usually shows optical anomalies though in part it is quite isotropic. In the more massive types the growth of the crystals was interrupted, and the grains are more or less rounded from interference. Towards the calcite the garnet almost invariably presents sharp crystal forms. The intricate system of minute fractures throughout the mineral, is filled with the metallic minerals along with quartz, calcite, and chlorite. The latter mineral is an alteration of garnet along the minute shear planes.

Actinolite (Magnesium-calcium-iron amphibole).—Actinolite is comparatively rare and is as a rule only distinguished microscopically. It occurs associated with the other minerals as pale green fibrous and felty masses, and in lath-shaped individuals with frayed terminal faces. A considerable proportion of the chlorite may have been derived from actinolite.

Tremolite (Lime-magnesia silicate).—Tremolite is rare and was only distinguished microscopically. It is colourless or turbid from minute dust-like inclusions, and occurs in oblong forms with frayed terminals, or as irregular sheaf-like aggregates.

Sericite (Hydrous variety of muscovite mica).—Sericite is also very rare and of microscopic occurrence. It appears in colourless plates and leaves which are usually bent or crumpled.

Chlorite (Hydrous silicate of variable composition).—Chlorite is prevailingly present in varying amounts in all types of the gangue rocks. It varies in colour from green to brownish green, and appears as platy aggregates and fibrous mats. It surrounds grains of quartz and calcite, and is also found as rounded clusters of scales included in them. In the later vein filled fissures, the chlorite usually forms the outer zone of the banded vein. A very small proportion of the chlorite is derived from the alteration of epidote and garnet, and a large proportion may have been derived from the alteration of actinolite, but there is little definite data on this point.

Oxides.

Quartz (Oxide of silicon).—Quartz in light and dark grey tones occurs in lenticular and rounded aggregates both microcrystalline and chalcedonic. It also appears in angular and rounded grains, and in crystals with double pyramids, in calcite and chlorite. It is in great part of the same age as the calcite and when together both show mutual intergrowth, and an irregular interlocking habit. With calcite it fills fine fracture planes in the other gangue minerals, and occurs banded with the former in veins occupying the larger fissures.

Carbonates.

Calcite (Carbonate of lime).—Calcite, of milk white, light grey or pale pink colour, is one of the most abundant of the gangue minerals, and with quartz was deposited, in part at least, later than the lime-iron silicates. In the more open portions of some of the fissures it formed druses with crystals up to 3 inches in diameter which are combinations of the rhombohedron and prism (Plate IV A). More generally it occurs in small angular and irregular grains and individuals up to 3·5 mm. in diameter, and in sponge-like masses of indefinite area which include small grains of all the other minerals both metallic and non-metallic. It is in part contemporaneous, and in part later than the quartz, and probably represents the residual uncombined portions of the original limestone.

Phosphates.

Apatite.—Apatite is extremely rare and was only noted microscopically in two instances where it occurred in minute crystals and needles embedded in grains of quartz.

ORIGIN OF THE DEPOSITS.

The copper-gold-silver deposits at Phoenix occur in that portion of a zone of contact metamorphism, characterized chiefly in its mineral composition by the abundant development of epidote and garnet. In a genetic classification of ore deposits by Weed,[1] those of the Boundary district, British Columbia, have been referred to the Cananea type owing to the importance of the ore mineral chalcopyrite.

The original limestone, which appears in fragmentary exposures adjacent to, and in contact with the ore bodies, and as residual masses included in them, is comparatively pure and contains with the exception of silica only minute quantities of iron and alumina (see analyses p. 34). The metasomatic replacement of the limestone by epidote and garnet with minor amounts of actinolite, tremolite, and zoisite has evidently been brought about by the introduction of ferric iron, alumina, and additional silica. The contact between the replaced and original limestone is usually sharp, but thin sections show the development of epidote and garnet at considerable distances from the actual contact, in the main bodies of the limestone. Calcite and quartz are invariably associated with the lime silicates, usually filling interspaces between the grains of the latter.

The solutions carrying the ferric iron, alumina, and silica were probably above the critical point (365 degrees temperature, and 200 atmospheres pressure for water), and consisted mainly of water gas strongly ionized. A certain quantity of the limestone passing into solution, combined with corresponding quantities of the ions of the material already in solution, which resulted in the formation of lime-iron and lime-iron-aluminium silicates according to physico-chemical laws. This general molecular replacement in large masses of limestone would also result in the liberation of large quantities of carbonic gas and carbonated waters, which would pass out and beyond the zone of mineralization.

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[1] Weed, W. H. Ore Deposits near Igneous Contacts. Trans. Amer. Inst. Min. Eng., Vol. 33, 1902, pp. 715-746.

The formation of magnetite was probably contemporaneous with that of the epidote, garnet, etc. It occurs in isolated masses (some of which are important as distinct ore bodies), at various horizons particularly at or near the edge of the mineralized zone. When the formation of the epidote, etc., had been well advanced the general character of the solutions changed somewhat and chalcopyrite, pyrite, and hematite were introduced, and deposited in, and along the numerous minute cavities and fractures, the general circulation of the solutions being guided primarily by the system of fissures developed through the whole zone.

This zone of contact metamorphism, which includes the crystalline limestone and the mineralized zone, is characterized by the absence of closely associated igneous intrusive bodies of sufficient importance to cause the extensive metamorphism which has taken place in the original limestone. The nearest outcrops of granodiorite lie from one to two miles away, and exploratory drilling, extending to a depth of at least 1,200 feet below the base of the contact zone, has encountered no important masses of igneous rocks.

It has been assumed, without, however, any direct evidence, that certain intrusions of the granodiorite batholith occurring in the district, have been the cause of the metamorphism of the limestone, and the source of the mineral solutions which have metasomatically replaced so large an area of the limestone by lime silicates, followed by the deposition of the metallic minerals.

If such is the source, the mineral bearing solutions given off by the igneous masses sought out the more favourable beds of limestone, which at that time would be deeply buried under an unestimated thickness of overlying rocks, but still situated in the zone of fracture. The solutions would traverse the limestone in lateral directions, and in cases lateral descending directions, replacing the limestone by the lime silicates, and later on depositing the ore. This view appears to be confirmed by the ore which terminates gradually or sharply with depth finally giving place to limestone or jasperoid. In the accompanying figure (Fig. 7), and also in a previous one (Fig. 6, p. 61), the ore is seen terminating against limestone, and also against the tuffs of the jasperoid zone, where the limestone has been completely replaced.

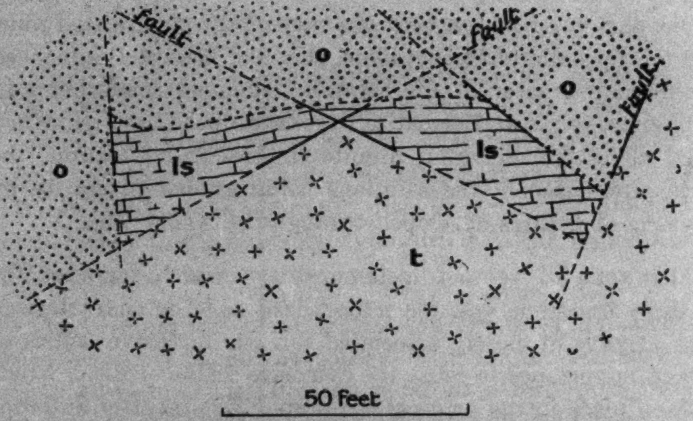

FIG. 7.—Knob Hill-Ironsides Mine, 300 ft. level. Tuffs (**t**), limestone (**ls**) and ore (**o**). Ore replacing limestone.

The granodiorite, as noted by Brock[1], and also by the writer on the Laxie claim near Phoenix, has locally been replaced by garnet, epidote, and actinolite. This condition may be due to an early solidification of the magma in certain areas, which were later attacked by solutions given off by more recent intrusions considered in the above hypothesis. Syenite porphyries supposed to be connected with the plutonic rocks of the batholith cut the mineralized zone and no doubt represent the final phase of the long extended intrusion.

Granite and quartz porphyries occurred at levels relatively higher than Phoenix during early Tertiary, and a great portion of the sediments of the Kettle River formation overlying part of the zone of contact metamorphism is composed largely of disintegrated rocks of the above types, none of which is found outcropping in the vicinity of Phoenix at present. These may possibly represent the hypothetical intrusives.

With regard to the origin of such a zone of contact metamorphism in limestone formations there is considerable diversity of opinion among many of the more eminent authorities. On the one side it is maintained that the results are brought about by the metamorphism of impure limestone, at and adjacent to the contact of igneous intrusive rocks, with little or no addition of material from the latter, while on the other side, the view is advanced, that foreign material from igneous sources has been introduced into the limestone which has caused the metasomatic replacement of the rock.[1]

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[1] Brock, R. W. Sum. Rep. Geol. Sur. of Can., 1902, p. 109.

From the great diversity of and variation in deposits in contact zones of this character, it would appear that broad generalizations cannot be made from a few or even from a great number of isolated examples. In certain instances pure limestone bands only are replaced, while in other cases the impure bands alone have the lime silicates developed. Besides the character of the replaced rock, the composition of the magma of the intrusive rock is probably an important factor, as well as the size and attitude of the igneous mass.

As far as the ore deposits and zone of contact metamorphism at Phoenix are concerned, the foreign material believed to have been derived in great part, if not all, from igneous sources, played the most important part in the replacement of the limestone, as well as in the formation of the ore bodies.

The evidence derived from a number of similar zones in other districts, shows that the deposits do not occur at the actual contact between igneous and sedimentary rocks, but may be hundreds or even thousands of feet away from such contacts. At Phoenix, however, evidence of this character is entirely wanting, erosion has removed all traces of igneous rocks, if they originally existed in association with the mineralized zone, and even the latter and the ore bodies themselves have suffered considerably from the same agencies.

AGE OF THE DEPOSITS.

The age of the deposits cannot be definitely placed with reference to the geological time scale. If the hypothetical assumption regarding the origin of the ore discussed in the foregoing paragraphs be the correct solution, the formation of the ore bodies occurred in some period subsequent to the initial invasion of the granodiorite batholith of the district, and prior to the intrusion of the final phases of the batholith, as indicated by the dykes of syenite porphyry which cut the mineralized zone. The provisional age of the ore bodies would, therefore, be placed as Jurassic (?).

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[1] Kemp, J. F. Ore Deposits at the Contacts of Intrusive Rocks and Limestones. Econ. Geol., Vol. 2, 1907, pp. 1-13.

Lindgren, W. The Relations of Ore Deposits to Physical Conditions. Econ. Geol., Vol. 2, 1907, pp. 105-127.

Lindgren, W. Copper Deposits of the Clifton-Morenci District. U. S. G. S. Prof. Paper 43, pp. 160-164.

Barrell, J. Physical Effects of Contact Metamorphism. Amer. Jour. of Science, Vol. 13, 1902, pp. 279-296.

FUTURE OF PHOENIX CAMP.

The exploratory and development work on the different deposits, and in the mineralized zone generally, has been of such a character as to prove almost conclusively that all the large ore bodies occurring in the zone have been located, and their size and importance approximately estimated. More detailed work, such as diamond drilling at closer intervals, may lead to the discovery of smaller and more or less isolated deposits, which may be mined to advantage. It is also possible that before the main ore deposits have been exhausted, other conditions may arise that will permit of the extraction of the lower grades—not considered as ore at present—on a commercial basis. If such should be the case the life of the camp would be prolonged for a period not readily estimated at the present time.

CHAPTER VI.

DETAILED DESCRIPTION OF MINES.

The Granby Consolidated Mining, Smelting, and Power Company, Limited.

INTRODUCTION.

Location.—The mines of the Granby Consolidated are situated in and adjacent to the city of Phoenix. The Company owns 43 claims and fractions, comprising in all 1,050 acres. Of these claims 14 are located either wholly or in part on the mineralized zone. They are the Old Ironsides, Knob Hill, Victoria, Aetna, Grey Eagle, Aetna fraction, Missing Link, Gold Drop, Gold Drop fraction, Monarch, Curlew, Phoenix, Fourth of July, and Gilt Edge (Fig. 4, p. 54).

History.—The best known claims are the Old Ironsides and Knob Hill, which were originally operated under the auspices of two financially connected companies namely, the Old Ironsides Gold Mining Company, Ltd., and the Knob Hill Gold Mining Company, Ltd. With these was connected the Granby Consolidated Mining and Smelting Company, Ltd., the three being known as the Miner-Graves Syndicate. The latter Company built a smeltery at Grand Forks on the North fork of the Kettle river about 24 miles from Phoenix, for the treatment of the ores from the above-mentioned mines.

Systematic development was begun at the mines during the winter of 1895, and on July 10, 1900, the first shipment of ore, consisting of 300 tons, was sent to the smeltery. The first furnace was blown in on August 21 of that year, and from then to the present, with the exception of a short period at the close of 1907, both mines and smeltery have been in continuous operation.

In 1901, the above-mentioned companies, together with the Grey Eagle Gold Mining Company, Limited, were consolidated into the Granby Consolidated Mining, Smelting, and Power Company, Limited, with a capital of $15,000,000. The holdings at the time were 11 claims and fractions at Phoenix, and the smelter, converter, and power plants at Grand Forks. Since that time the holdings have been increased at Phoenix, the most important additions being the Monarch mine, purchased in 1904, the Gold Drop group in 1905, and the Curlew in 1907. The smeltery has also been enlarged and the daily capacity increased from 600 tons in 1901, to between 4,000 and 4,500 tons in 1910. About 450 men are employed at the mines and 350 at the smeltery.

Production.—The total production of the Granby mines to July 1, 1910, amounted to 6,263,091 tons. In addition, 214,544 tons of foreign ore, and 13,514 tons of foreign matte, were smelted with the Granby ore, giving a total of 6,491,149 tons. From this tonnage the metal returns and values were:—

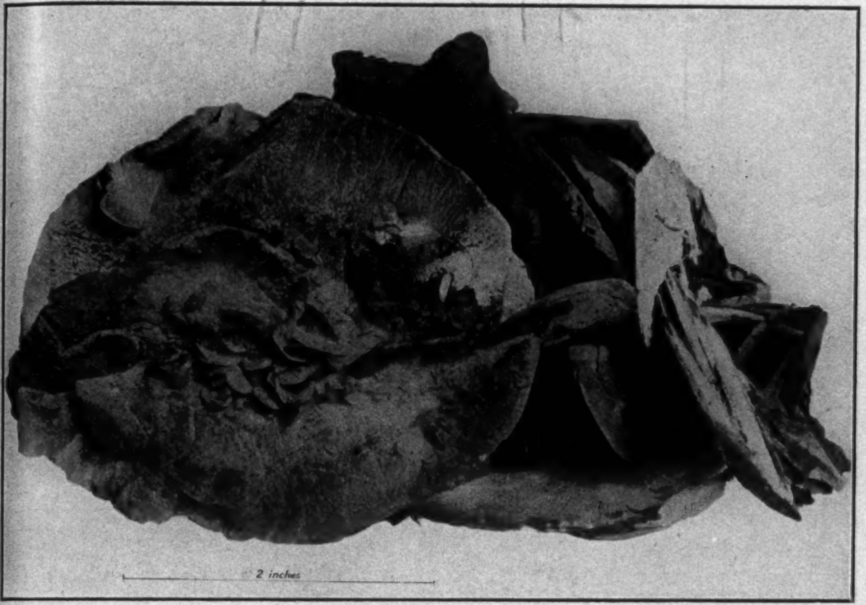
Gold, 401,280 ounces..............	$ 8,025,662.22
Silver, 2,690,055 ounces...........	1,533,555.36
Copper, 161,017,120 pounds........	23,203,005.46
Total	$32,762,223.04

Ore Reserves.—In the last annual report of the Company, Mr. O. B. Smith, superintendent of the Granby Consolidated Mines, stated that the amount of ore blocked out in October, 1910, amounted to 6,429,169 tons, of which it is expected that 90 per cent can be extracted. The average contents are: copper 1·25 per cent, gold 0·043 ounces, and silver 0·25 ounces per ton.

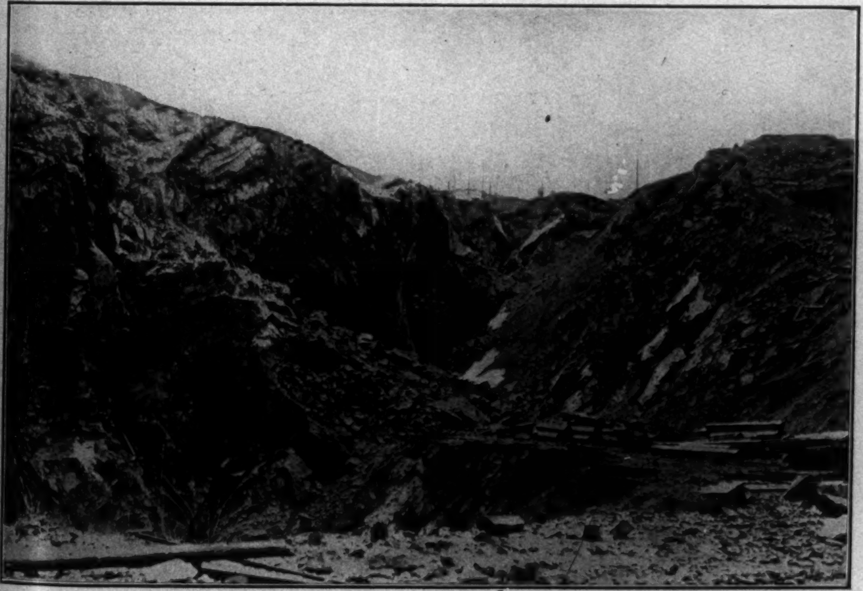
Dividends.—Dividends have been declared from time to time during the past seven years, the first being in December, 1903, the last in December, 1910. The total amount paid to the shareholders has been $3,928,630.

Equipment and Transportation.—The ore from the mines at Phoenix is handled by four separate units, namely, No. 2 and No. 3 tunnels and the Victoria shaft for the Knob Hill-Ironsides mine (Plate I, Frontispiece), and the Curlew tunnel for the Curlew, Gold Drop, and Monarch mines. Each unit is equipped with crushers and ore bins. With the exception of No. 2 tunnel unit, where the ore drops directly into the bins, belt conveyers are used from crusher to bin. The combined capacity is about 600 tons per hour.

No. 3 tunnel is connected with the Great Northern railway, the Curlew with the Canadian Pacific, while No. 2 tunnel and



(*a*) Calcite druse.



(*b*) Knob Hill-Ironsides mine, north end of main glory hole, 1909.

the Victoria shaft are connected with both railways. This ensures uninterrupted shipping facilities in case of individual accident, either to the units or the railways. The ore is shipped to the smelter in 30, 40, and 50 ton cars.

Electricity is used throughout both for power and light. The high tension power lines of the West Kootenay Water and Power Company, and the British Columbia Construction and Distributing Company, are capable of delivering 7,000 H. P. at Greenwood. Their lines, switching apparatus, transformers, and generators are in duplicate, which practically ensures continuous power. Air power is supplied by two cross compound duplex, 60 drill tandem, air compressors.

Methods of Mining.—The methods of mining have altered as the ore bodies were developed, and their size, attitude, and character were more fully understood. The ore bodies are mined along their outcrops by large open quarries or 'glory holes,' and underground by a system of tunnels and shafts. Timbering the stopes by the square set system has long been abandoned as impracticable, and the pillar and room method is used entirely in mining all ore below the levels of the 'glory holes.' Generally two or more tunnels are driven with the strike of the ore body. From these raises are driven every 45 feet at an angle of 45 degrees, connecting with each other at 30, and 60 feet, and with the level above. The size of the pillars, and their number, depend upon the character of the ground traversed.[1] The preliminary prospecting work is done by diamond drilling and is kept well ahead of the regular development work.

General Development.—The total development in all the Granby mines to the end of 1909 in tunnels, drifts, and cross-cuts amounted to 73,679 feet (lineal) and the work is progressing at the rate of about 1,000 feet per month. The total length of the diamond drill holes to the same date amounted to 43,684 feet.

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[1] Campbell, C. M. Granby Mining Methods. Jour. Can. Min. Inst., Vol. XI, 1908, pp. 392-406.

Composition of the Ores.—An average analysis of the Granby ores gives the following percentages:—[1]

SiO_2	35
Fe	13
CaO	17
Al_2O_3	8
MgO	3
Copper	1·2 to 1·6

The chalcopyrite is the only copper bearing mineral, and it also carries all the gold and silver values.

Granby Smelter.[2]—The smelter at Grand Forks consists of eight blast furnaces capable of treating from 4,000 to 4,500 tons of ore daily, and 13 converting shells with a total annual capacity of about 36,000,000 pounds of blister copper. About 12½ per cent of coke is the average charge with the ore. About 85 per cent of the values is regularly recovered, the percentage of copper passing into the slag varying from 0·2 to 0·25 per cent. The matte at present contains from 35 to 40 per cent of copper, which is converted to blister copper 99 per cent pure carrying the gold and silver values. It is cast into 220 pound bars and shipped to New York for refinement.

The Knob Hill-Ironsides Mine.

Location.—The Knob Hill-Ironsides mine is situated in and to the south of the city of Phoenix, and comprises in its workings a group of 5 claims, namely, the Knob Hill, Old Ironsides, Victoria, Aetna, and Grey Eagle. (Fig. 4, p. 54).

Development and Equipment.—The mine is developed by a series of 'glory holes' along the outcrop of the ore body (Plate I, Frontispiece, and Plate IV B), and by six levels, the upper three being Nos. 1, 2, and 3 tunnels driven on the strike of the ore body, and the lower three being the 200, 300, and 400 foot levels with shaft connexions to the surface. The Victoria shaft is an incline three compartment connecting the three lower levels. All ore below the level of No. 3 tunnel is conveyed to pockets

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[1] Lathe, F. E. Recent Developments at the Granby Smelter. Jour. Can. Min. Inst., Vol. XIII, 1910, p. 280.

[2] Lathe, F. E. Recent Developments at the Granby Smelter. Jour. Can. Min. Inst., Vol. XIII, 1910, pp. 273-287.

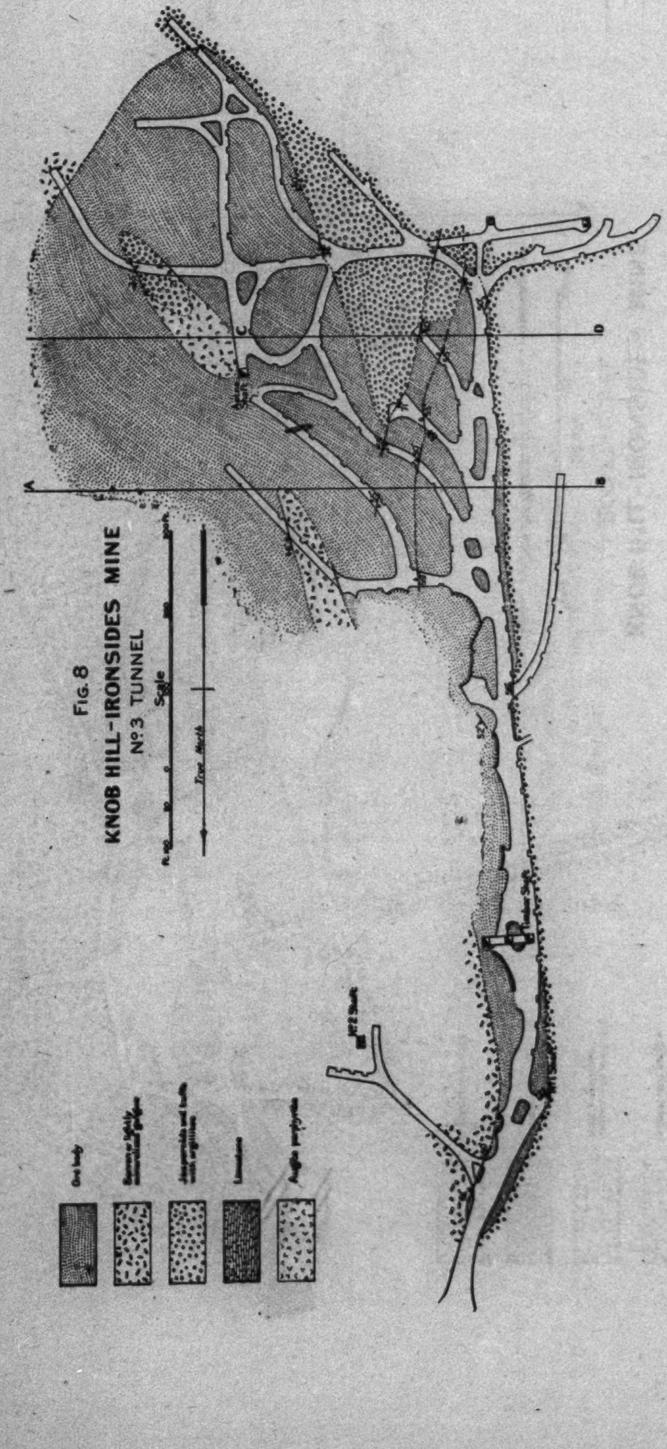


Fig. 8

KNOB HILL-IRONSIDES MINE

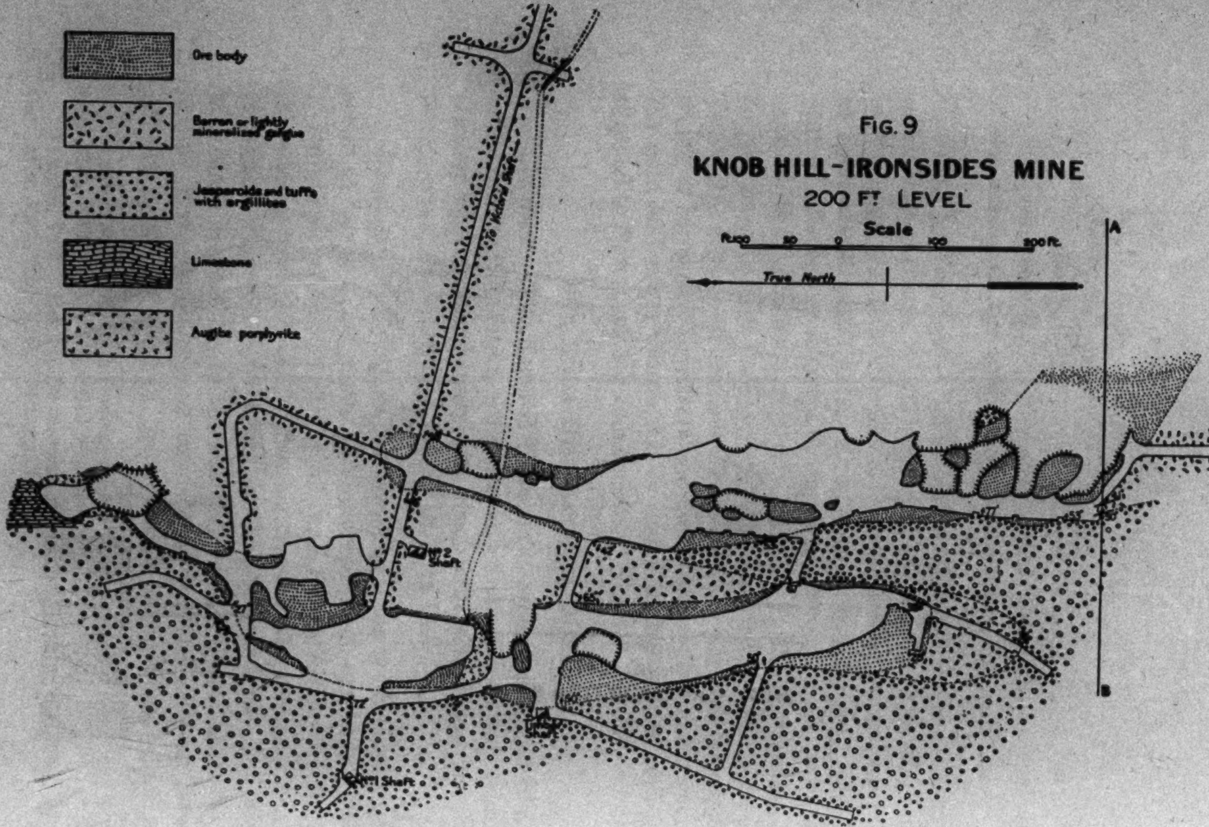
No. 3 TUNNEL

Scale
True North
A
B
C
D
No. 2 Shaft
Ore body
Agglomerate and tuffs with argillites
Limestone
Augite porphyrite

FIG. 9

KNOB HILL-IRONSIDES MINE

200 FT. LEVEL


Ore body
Barren or lightly mineralized gangue
Jasperoids and tuffs with argillites
Limestone
Augite porphyrite
Scale
Ft. 100
50
0
100
200 Ft.
True North
A
B
To Victoria Shaft
No 2 Shaft
No 1 Shaft
Aetna Shaft

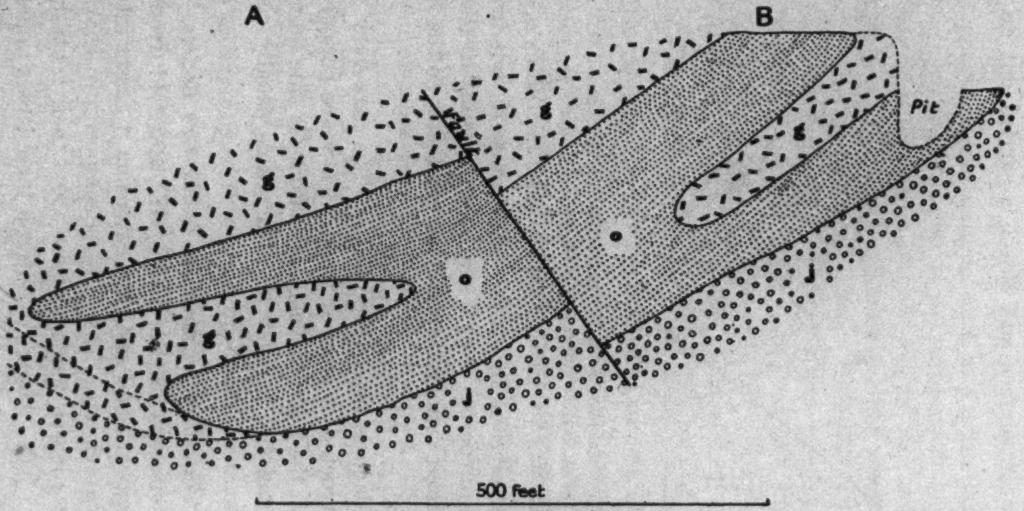

A
B
Pit
Fault
g
g
g
g
o
o
J
J
J
500 feet

Fig. 10.–Section B–A across ore bodies.
Knob Hill–Ironsides Mine.
Ore (o), gangue (g), jasperoids, and tuffs (j).

below the 300 and 400 foot levels, and hoisted through this shaft in 5 ton skips, averaging about 1,000 tons per 8 hour shift. No. 1 tunnel has been abandoned as an avenue of outlet, and all ore mined from between surface and No. 2 is carried out on that level. No. 4 tunnel runs in on the 300 foot level, but is only used for limited purposes. No. 2 shaft also extends to the 400 foot level and is used mainly for carrying steel, etc., to the lower levels.

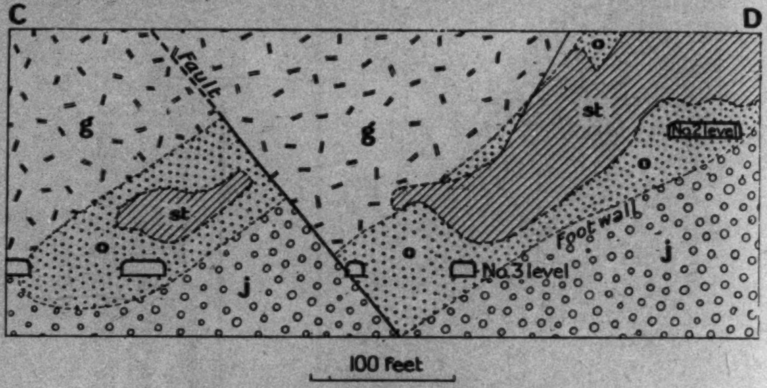


Fig. 11.—Section D—C across ore body.
Knob Hill-Ironsides Mine.
Ore(o), gangue(g), jasperoids and tuffs(j), stopes(st).

Electric haulage is used throughout. The cars vary from 3 to 10 ton constructed of steel or wood. They are hopper and gable bottomed on the tunnel levels, and automatic side dumping cars on the 300 and 400 foot levels. The trains usually consist of about eight cars.

Geological Relation and Character of the Ore Bodies.—The main ore body outcrops on the Knob Hill and Old Ironsides claims; in its downward and eastward extension it passes into the Victoria and Aetna claims. The body is composite in character and consists of two lenses which coalesce about their central portions (Figs. 8 and 10). Along the outcrop these lenses appear as two distinct bodies separated by a varying thickness of the gangue rocks. The western lens is at least 2,500 feet long, from 40 to 125 feet thick, and from 370 to over 900 feet wide. (Fig. 10 and 11, pp. 77 and 78). The eastern lens is apparently not so long, but approaches the magnitude of the former in width and thickness. The combined thickness of the two at their point of junction is about 187 feet (Fig. 10, p. 77). In its southern extension this composite ore body appears to break up into subordinate ribs or wedges of ore (Fig. 5, p. 59), separated by complementary ribs of almost barren gangue rock, and a similar condition also appears to occur to the east of the main ore body, where a rather flat lying zone, consisting in part of pay ore, has been found on about the same level as No. 3 tunnel. The general strike of the outcrop of the ore body is N. 10° E., with dips to the east ranging from 45 to 60 degrees. The dip flattens with depth and on the lower levels averages from 15 to 30 degrees. The general pitch of the ore body is about 18 degrees to the northeast. The vertical range of the ore body from the south end of the main 'glory hole' to the lowest working level is 675 feet.

The ore body lies in a basin-shaped trough, the floor of which consists mainly of the rocks of the jasperoid zone of the Brooklyn formation, with local areas of Brooklyn limestone (Fig. 9, p. 76) and the siliceous rocks of the Knob Hill group. In the main, however, the jasperoids form the structural foot-wall (Figs. 8 and 9), and the ore body is usually in sharp contact with it, except locally where bands of gangue rock from a few inches to a hundred or more feet in width intervene (Fig. 9, p. 76), thus introducing in part a commercial foot-wall. At the north end of the west ore body, the rock adjacent to the ore is a grey siliceous crystalline limestone which extends from the 200 to below the 400 foot level (Fig. 9, p. 76).

The hanging-wall is a purely commercial one, and the ore either grades insensibly into barren gangue, or is sharply bounded by a gouge filled fissure (Fig. 9, p. 76).

Fissure System.—The ore bodies and the adjacent rocks are traversed by an intricate system of fissures ('slips') which run in all directions and dip at all angles. The major fissures tend to preserve a northerly trend with dips either to the east or to the west (Fig. 8, p. 75). They vary from those hundreds of feet long down to those of microscopic dimensions. They had a most important influence on ore deposition, since they formed an intricate and reticulating system of channels for the ore bearing solutions, which permitted the uniform distribution of the ore, so characteristic of the deposit. Many of the fissures have been filled with ore and banded quartz and calcite, and it is a noticeable feature in places, that the ore adjacent to them is rather above the average grade. Some of the fissures remained open in certain portions, and large and beautiful druses of calcite crystals were formed along their walls (Plate IV A). No noticeable displacements accompany the fissure system except along the major fissure traversing the ore body, which has a throw varying from zero to 120 feet. The strike of this fault is N. 12° E. and the average dip of 55 degrees to the west (Figs. 8, 10, and 11).

Igneous Rocks.—The ore bodies are cut by dykes of alkaline syenite porphyry (pulaskite) and augite porphyrite of Tertiary age. In the underground workings none is found above the No. 3 tunnel level. They increase in number with depth. It was not possible to trace them continuously for any distance, except in the case of one dyke of augite porphyrite on the 200 foot level (Fig. 9, p. 76), which is apparently persistent from back to the foot-wall, to a cross-cut near the Victoria shaft. They are considerably altered by shearing, and by the development of secondary minerals. Narrow veinlets of calcite and feathery pyrite occur filling some of the more prominent planes.

Character of Ore.—The ore consists of chalcopyrite, which with pyrite and hematite in grains and granular aggregates, is finely and uniformly distributed through a gangue, composed almost exclusively of garnet, epidote, calcite, quartz, and chlorite. The pyrite is usually in small grains, streaks, and crystals, and the hematite (specularite) in platy aggregates. Magnetite occurs in masses and irregular lenses of varying size at intervals through the ore body, but they are relatively unimportant.

Banded ore occurs in the surface zone and at different points in some of the lower stopes. Adjacent to limestone the ore has usually a greater proportion of calcite as a gangue mineral with a noticeable increase in the pyrite content. Occasionally thin bands of very siliceous pyritic ore are developed at or near the foot-wall. Lenses and pockets of more massive and higher grade chalcopyrite are frequently met with, but they are small and relatively unimportant. The average content of the ore is: copper

1·25 per cent, gold 0·04 ounce, and silver 0·3 ounce per ton. The values are entirely in the chalcopyrite. Along the outcrop the ore has suffered from the leaching action of oxygen bearing waters, which has in places produced an ore of lower grade extending to a varying depth, without any noticeable secondary enrichment at lower levels.

THE GOLD DROP MINE.

Location.—The Gold Drop mine is situated on the east slope of Knob Hill ridge about one mile from the Knob Hill-Ironsides mine. It adjoins the Rawhide and Monarch to the south, and the Snowshoe to the east (Fig. 4, p. 54).

Development and Equipment.—The mine is developed by three 'glory holes' along the outcrop of the ore body, and by No. 3 and the Rawhide drift tunnels driven on the strike of the ore body (Plate V.). No. 3 tunnel or the Monarch drift, with five parallel drifts to the east of it, divides the ore body into oblong blocks. The Monarch drift is the main avenue of transportation, and is connected near its southern extremity by a raise to the Monarch mine. Near the north end a long raise connects the mine with the Curlew tunnel. All ore won from the Monarch, Gold Drop, and Gold Drop No. 1, is dropped down the Curlew raise, and is conveyed through the Curlew tunnel, to the terminal on the Canadian Pacific railway. Electric haulage is used throughout.

Geological Relations and Character of the Ore Body.—The Gold Drop mine develops only part of an extensive and practically continuous ore body, which outcrops on the Gold Drop claim, swings down and across the Rawhide and Curlew, and terminates on the Snowshoe claim. The whole, when broadly viewed, has, on a horizontal plan, the form of a compressed crescent with northward trending horns, broken by the occurrence of the detached ore body of Gold Drop No. 1 and the north body of the Snowshoe. The ore body rests on a floor of jasperoids, and in the Gold Drop proper there is an entire absence of Tertiary intrusives, or remnants of the Brooklyn limestone. The ore body of the Gold Drop proper is developed in the southeast part of the Gold Drop, and northeast part of the Monarch claim. The strike varies from N. 13° E. to N. 32° E., with an easterly dip, which averages about 40 degrees, but flattens to about 25 degrees below the level of the Monarch drift. To the northwest of the drift, the foot-wall steepens to 70 degrees and over, owing to a narrow wedge of jasperoid, which breaks through to the surface, and

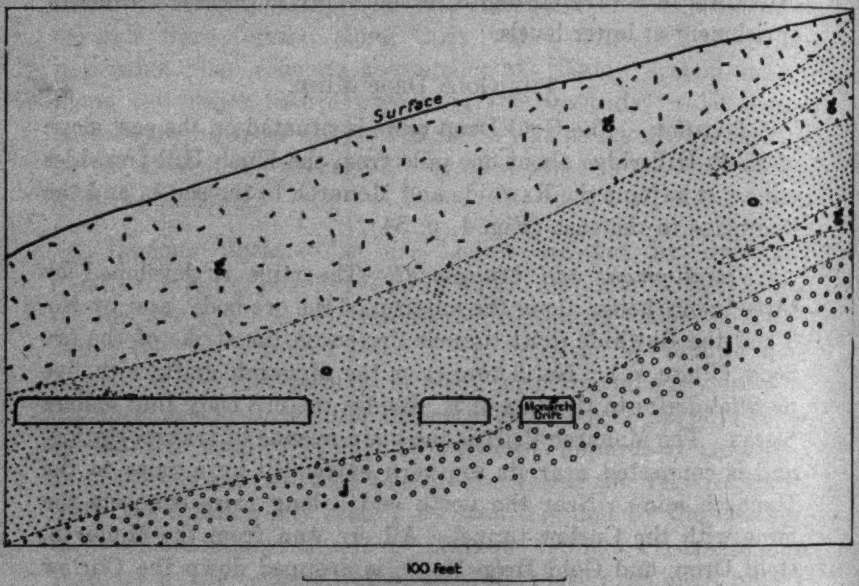


Fig. 12.—Gold Drop Mine, No. 3 level.
Showing portion of ore body.
Ore(o), gangue(g), and jasperoid (j).

locally divides the ore body into two forks. The hanging-wall is a commercial one, as well as parts of the foot-wall, and the pay ore is usually bounded by more or less well marked fissures (slips). The average pitch of the ore body is 7 degrees to the north and northeast.

The known length of the ore body along the strike of the Monarch drift is over 750 feet, and its width to the boundary of the claim is about 315 feet. The thickness probably averages about 30 feet, the diamond drill logs showing a range from 7 to 55 feet (Fig. 12, p. 82).

The system of fissures (slips) common to all the ore bodies is well developed in this instance. The ore body is not uniform throughout, in its metallic contents, and ribs or wedges of the gangue minerals occur in several parts of the mine, which, depending on their size and situation, are either stoped out or left standing.

Character of Ore.—The average ores do not show any variation either in gangue or metallic minerals from the usual types. The values as determined from assays of the drill cores give from 1·12 to 3·2 per cent copper, 0·02 to 0·07 ounce of gold, and 0·2 to 0·6 ounce of silver per ton.

GOLD DROP NO. 1 MINE.

Location.—The mine is situated in the northeast part of the Gold Drop claim, about 600 feet north of the Gold Drop mine.

Development.—The mine has been opened up by a tunnel with two cross-cuts, which have delimited the ore body in all directions on that level. The tunnel is on the same level as the Monarch drift of the Gold Drop, and the former is connected by track and trolley to the Curlew chute.

Ore Body.—The ore body is comparatively small and of elliptical form, with a length of 300 feet, a width of 90, and a thickness of 25 feet. It lies in a rather flat basin, the floor of which is composed of the rocks of the jasperoid zone, and in part by quartzose crystalline limestone. It is overlain in part by the lava of the Midway Volcanic group. The ore is of average grade.

THE CURLEW MINE.

Location.—The Curlew mine is situated on a fractional claim of the same name lying between the Rawhide and Snowshoe (Fig. 4, p. 54). The ore has been developed by raises from the Curlew tunnel.

Ore Body.—The ore body is only a triangular section of the main body which extends from the Gold Drop to the Snowshoe, via the Rawhide claim. The Curlew portion is about 220 feet long, and up to 180 feet wide, with an average thickness of about 25 feet. It dips north into the Snowshoe at about 35 degrees, the foot-wall rocks being those of the jasperoid zone.

THE MONARCH MINE.

Location and Development.—The original Monarch mine is situated in the northwest quarter of the claim of that name, and has been opened up by an incline two compartment shaft 100 feet deep, with a small amount of drifting on that level.

During 1909, an important ore body not outcropping at the surface was located by drilling some distance east of the shaft. This has been developed by a tunnel connecting with the old workings at the shaft. A raise from the Monarch drift of the Gold Drop mine to the main tunnel of the Monarch allows the ore to be conveyed to the Curlew terminal.

Character of the Ore Bodies.—In the vicinity of the shaft, a shallow open-cut exposes an area of the mineralized zone in which narrow bands of magnetite occur with chalcopyrite and pyrite, and veinlets of the sulphides with hematite (specularite). The gangue is largely epidote and coarsely crystallized grey calcite. The calcite is often interbanded with magnetite which holds inclusions of the former. The banded ore varies in thickness from 18 inches to 3 feet. Along the west side of the open-cut the ore is much broken with considerable oxidation of the sulphides. The same general conditions prevailed in the old underground workings, there being no localization of the metals sufficient to constitute an ore body of any size.

The main ore body east of the shaft from present development is found to be roughly circular, with a diameter of about 140 feet and an average thickness of 30 feet. It is rather flat lying and dips at low angle to the southeast.

Character of the Ore.—The ore is largely magnetite, and carries 1·17 per cent copper, 0·03 ounce of gold, and 0·4 ounce of silver per ton. The ore body is the largest of that type which has been discovered at Phoenix up to the present.

THE GREY EAGLE MINE.

Location.—The Grey Eagle mine lies to the south of the Knob Hill-Ironsides mine, and adjoins the War Eagle of the Phoenix Amalgamated Group to the east.

Development.—The ore body has been prospected by diamond drilling, and developed by open-cuts and stripping, which has exposed a body of magnetite in places 30 feet thick, with a surface extent of over 4,000 square feet. It lies in a shallow flat floored basin composed of the rocks of the jasperoid zone.

Character of Ore.—The ore is a dense massive magnetite containing disseminated grains and crystals of pyrite with very small quantities of chalcopyrite. Garnet in masses and crystals occurs as inclusions in the ore. Owing to the comparatively small size and situation of the ore body, and its trifling copper content, it has not been considered feasible to mine the deposit at present.

THE GILT EDGE CLAIM.

The Gilt Edge claim lies to the north of Phoenix at the head of Deadman gulch. The exploratory work, consisting of a shallow shaft, some trenching, and a few diamond drill holes, has failed to discover any body of workable ore.

The mineralized zone as exposed is of slight superficial extent. It is cut off to the west by an intrusion of augite porphyrite, while to the east it is overlain by the Tertiary sediments and lavas. Northwards into Deadman gulch it is drift covered. The ground to the east inside the boundaries of the Tertiary rocks might be tested, but the structural conditions give little encouragement for the discovery of any large ore body.

FUTURE POSSIBILITIES.

The large area of the mineralized zone comprised in the Granby holdings has now been prospected by numerous diamond drill holes, and the ore bodies have been developed by extensive underground workings.

The work throughout has been of such a thorough and systematic nature that undoubtedly all the large ore bodies within the limits of the Company's property have been discovered. No doubt, in the further development of the mines, combined with diamond drill prospecting at closer intervals, the limits of the present known ore bodies will be extended in places, with possibly the discovery of smaller bodies in the adjacent ground, so situated as to be profitably mined with little additional dead work. Bands of mineralized gangue rock, between ore bodies, should be tested by drilling both in horizontal and vertical directions for the discovery of minor bodies or ribs of ore. Outside of the areas occupied by the main ore bodies, smaller bodies will undoubtedly be encountered, but so situated that present conditions would not permit of their profitable exploitation.

The Consolidated Mining and Smelting Company of Canada, Limited.

INTRODUCTION.

History.—This Company has been operating at Phoenix since 1906, when a lease was taken on the Snowshoe group, followed by the purchase of a group of 11 claims to the south of the Granby holdings known as the Phoenix Amalgamated.

The Snowshoe group consists of the Snowshoe, Pheasant, Fairplay, and Alma fractions. The ground covered by the Snowshoe was first staked by G. W. Rumberger in 1891, but the claim was allowed to lapse. It was relocated in 1893 by Dengler and Gibbs, who bonded it in 1897 to P. Clarke of Spokane. In 1899, it became the property of the British Columbia, Rossland, and Slocan Syndicate of London, and in 1901, after about 5,000 feet of work had been done, it passed under the control of the Snowshoe Gold and Copper Company, Limited, of London, which Company still owns the property. In 1906, the Snowshoe was leased to the Canadian Consolidated, who have been operating it since that time.

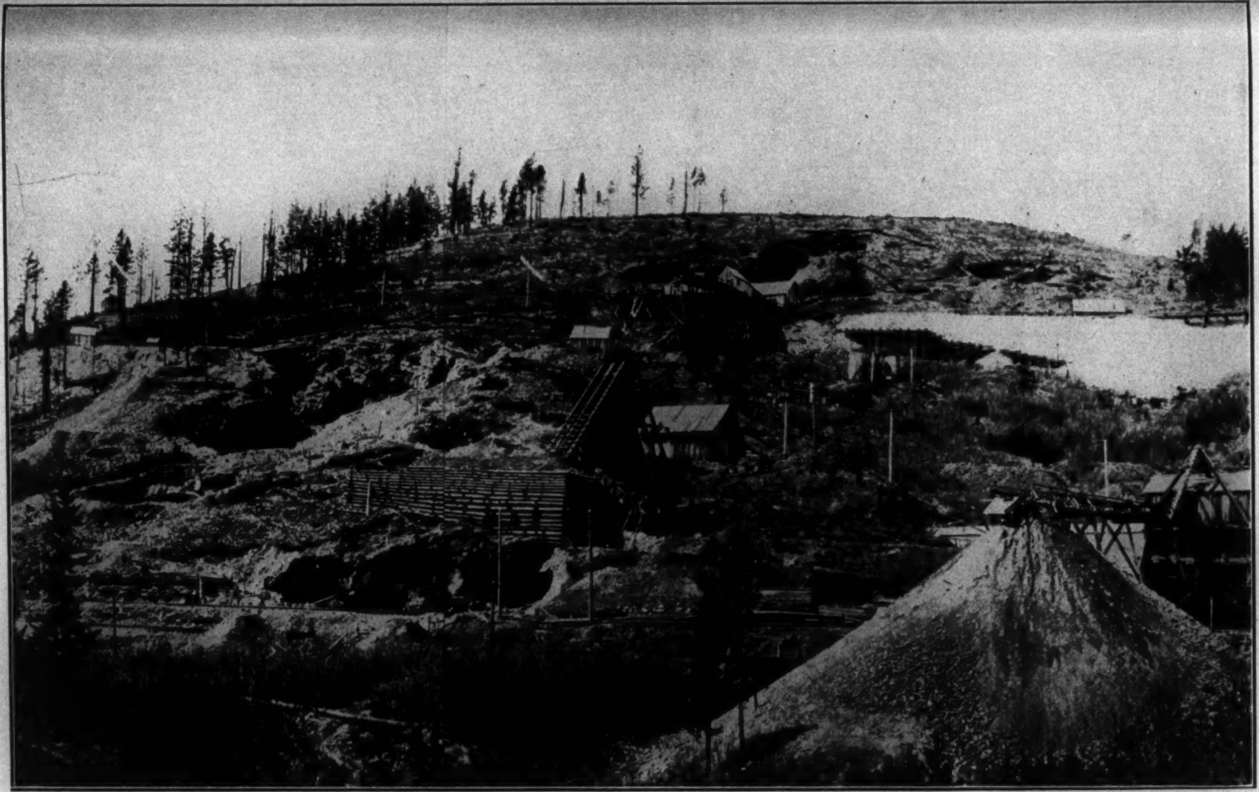
Production.—According to the last annual report of the Canadian Consolidated the total production of the Snowshoe to July 1, 1910, amounted to 520,092 tons of ore, containing 12,750,718 pounds of copper, 35,993 ounces of gold, and 137,978 ounces of silver, the gross value being $2,913,361.

The War Eagle of the Phoenix Amalgamated has only made trial shipments amounting to 249 tons, which yielded 2,214 pounds of copper, 7 ounces of gold, and 44 ounces of silver, the gross value being $451. The ore is shipped over the Canadian Pacific railway to the Company's smelter at Trail.

THE SNOWSHOE MINE.

Location.—The Snowshoe mine is situated to the east of Phoenix and adjoins the Gold Drop mine to the west, and the Rawhide and Curlew to the south. The four properties are practically on the same ore body.

Development.—The mine has been opened up on the outcrop by a series of six open-cuts and 'glory holes' or quarries, and underground by three tunnels and two shafts, with a sub-



Gold Drop and Snowshoe mines.

8359—p. 86.

ordinate system of drifts, raises, and cross-cuts. In all, over 10,000 feet (lineal) of work has been done in developing the ore body. The main tunnel runs across the ore body and passes into the foot-wall rock, the main drift turns off from it at right angles and connects with the main shaft and the upper workings at the north end of the mine (Fig. 13, p. 88). The main shaft (three compartment inclined) intersects the main level 97 feet below the collar, the second level at 197 feet, and the third at 212 feet. It will in future only be used to hoist ore from the two lower levels, as the main tunnel furnishes an avenue of outlet, for all ore stoped on and above that level.

Equipment.—Electric haulage is used in conveying the ore in two and three ton cars from the chutes, to the terminal bins, situated above a spur of the Canadian Pacific railway. Air power for drills, pumps, etc., is supplied by one-half of a 30 drill Rand compressor operated by steam power.

Methods of Mining.—The methods of mining are similar to those previously described, namely, a series of 'glory holes' for the surface portion of the ore body and pillar and room stopes for the underground. During the past two years (1909 and 1910) much of the ore has been won from the surface, particularly from the main 'glory hole,' where an electrically worked scraper is used to pull the ore down into the pockets.

Geological Relations and Character of the Ore Bodies.—On the surface there are two ore bodies separated by upward rolls in the (jasperoid) foot-wall rocks. They are conveniently described as the north and south ore bodies, and both are connected by the lower workings (Fig. 16, p. 92). In 1908 the lower workings—second and third levels—were filled with water, and the information regarding them has been derived from mine plans, sections, and personal consultations with the superintendents.

The South Ore Body.—The south ore body is a continuation of the one developed in the Curlew, Rawhide, and Gold Drop mines. It is broadly considered as one ore body, though bands, wedges, and ribs of slightly mineralized gangue rock break its continuity. These are removed or left in the stopes depending on their size and structure. Along the Snowshoe-Curlew bound-

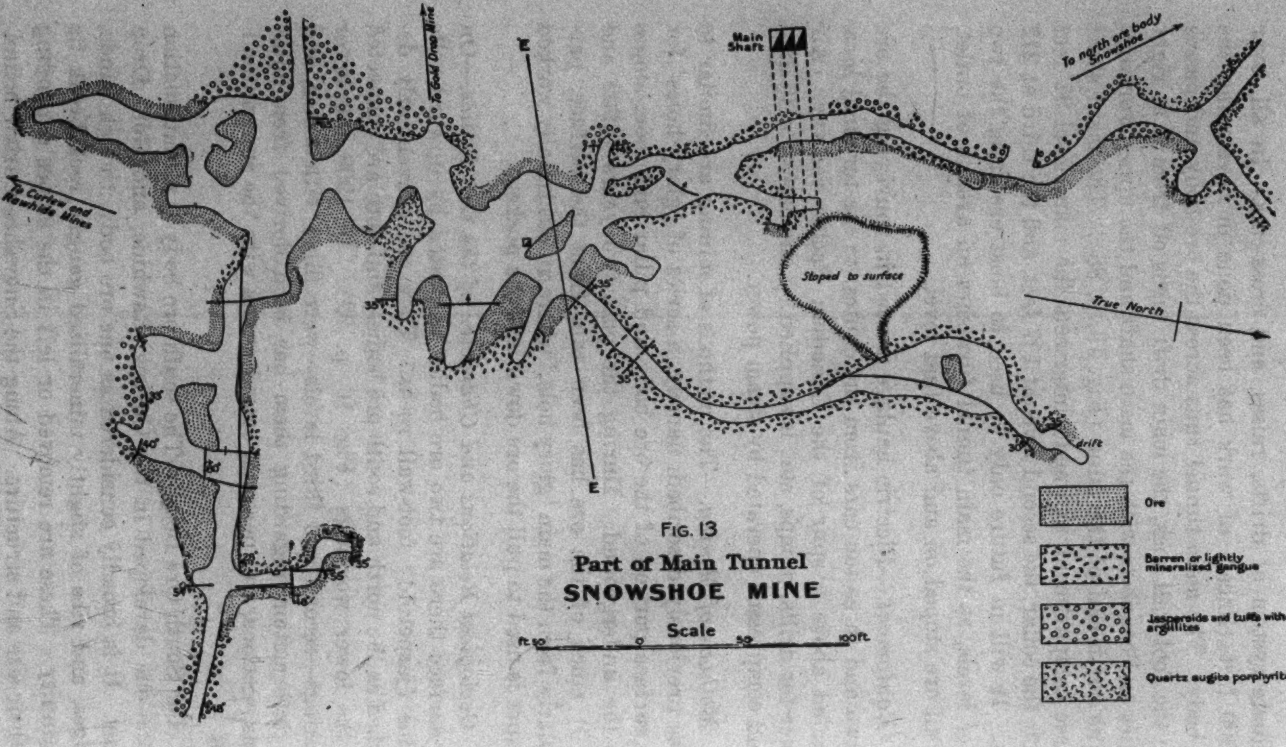

To north ore body Snowshoe
Main Shaft
True North
Stoped to surface
drift
E
E
To Gold Drop Mine
To Curlew and Rawhide Mines
35
30
45
Ore
Barren or lightly mineralized gangue
Jasperoide and tuffs with argillites
Quartz augite porphyrite
Scale
ft. 50
0
50
100 ft.

FIG. 13

Part of Main Tunnel
SNOWSHOE MINE

ary the foot-wall dips north at about 40°. To the west it then has a curving strike to the north with easterly dips ranging from

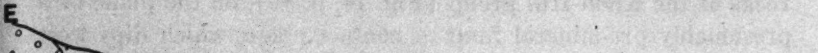


FIG. 14.— Section of Snowshoe ore body. Ore (o), gangue (g), gangue mineralized (g'), jasperoid (j), siliceous rocks Knob Hill series (KH).

30° to 65°. North of the main shaft at the first cross-cut, the strike is northeasterly with southeast dips from 40° to 50° (Fig. 13, p. 88). In its downward extension, the ore body apparently swings to the northeast, which brings it adjacent to, or in contact with the north ore body. The north and south axis of the ore body is about 580 feet long, and the east and west axis is about 270 feet long. The thickness of the ore according to cross sections varies from 26 to 35 feet with occasional local swells giving a greater thickness over small areas.

The foot-wall rocks are jasperoids, tuffs, red and grey argillites with local patches of quartzose crystalline limestone. The hanging-wall consists of the garnet and epidote rocks of the mineralized zone into which the ore either insensibly fades, or from which it is separated by a gouge filled fissure (slip). The ore body in depth terminates abruptly against the quartzose rocks of the Knob Hill group (Fig. 14, p. 89), on the plane of a presumably pre-mineral fault or contact plane, which dips west at from 15° to 38°. The ore body throughout is cut by numerous fissures which in places have a marked influence on the character of the ore, and which were the main channels of circulation of the ore bearing solutions (Fig. 13, p. 88). Many of these have been filled during the closing stages of deposition with quartz, calcite, chalcopyrite, and pyrite in banded arrangement.

Four dykes of augite porphyrite cut the ore body on the main level and run on approximately parallel bearings (Fig. 13, p. 88). They are very irregular, pinching and swelling with sharp rolls towards the horizontal. They have followed in part the lines of weakness of the more prominent fissure planes in the ore body.

Character of the Ore.—The ore is of the usual type, chalcopyrite and pyrite, with hematite (specularite), in a gangue of garnet, epidote, quartz, and calcite. Magnetite is found in but small amount, only two masses or lenses being noted in the workings above the main level.

The North Ore Body.—The north ore body was probably at one time connected surficially with both the South Snowshoe and Gold Drop No. 1 bodies, but has been separated by subsequent erosion.

From mine plans and sections the main part of the north ore body has a length north and south of about 370 feet on the surface, a width ranging from 110 to 150 feet, and is from 8 to 55 feet thick, the average being about 35 feet. The dip of the foot-wall varies from 18 to 56 degrees to the east. A fault dipping west at 12 degrees cuts the ore off. To the north this fault steepens to 47 degrees and with a displacement of about 40 feet brings the lower part of the ore body to the surface (Fig. 16, p. 92). The ore at this point lies on a dyke of augite porphyrite which has been intruded along the foot-wall. In its northern extension, the strike of the ore body swings to the northeast and the jasperoid foot-wall gives place to the quartzose rocks of the

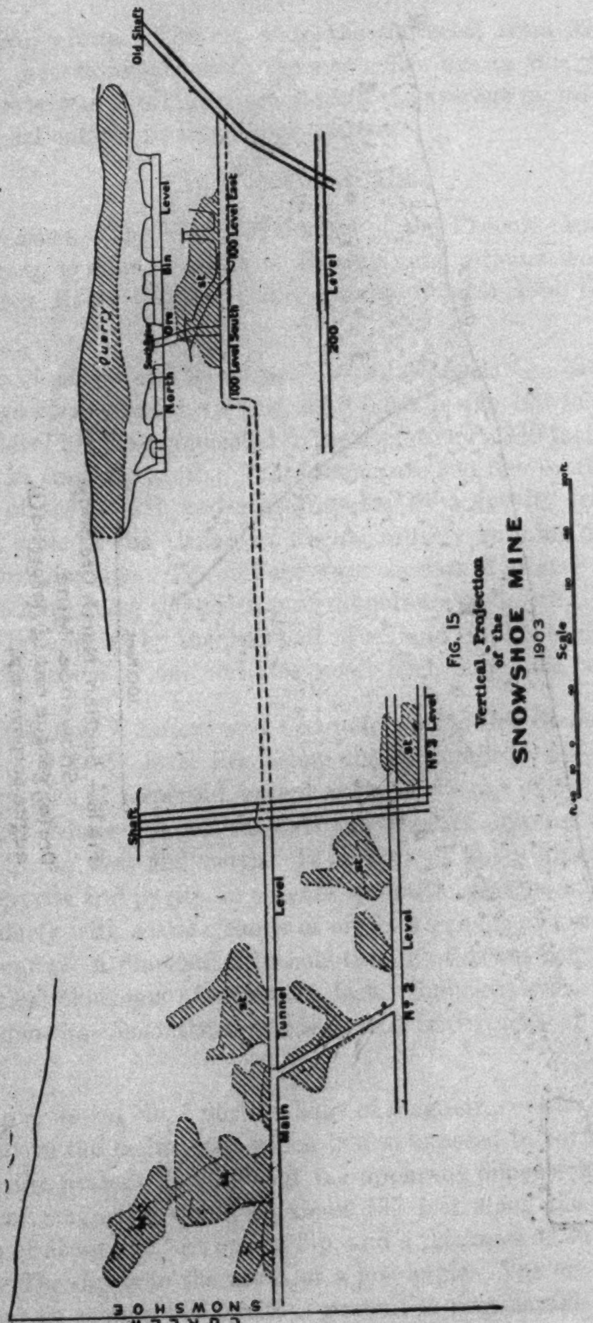

Old Shaft
Quarry
North
South
Ore
Bin
Level
st
100 Level South
100 Level East
200 Level
Shaft
No 3 Level
Main Tunnel Level
No 2 Level
CURLEW
SNOWSHOE
Scale

FIG. 15
Vertical Projection of the
SNOWSHOE MINE
1903

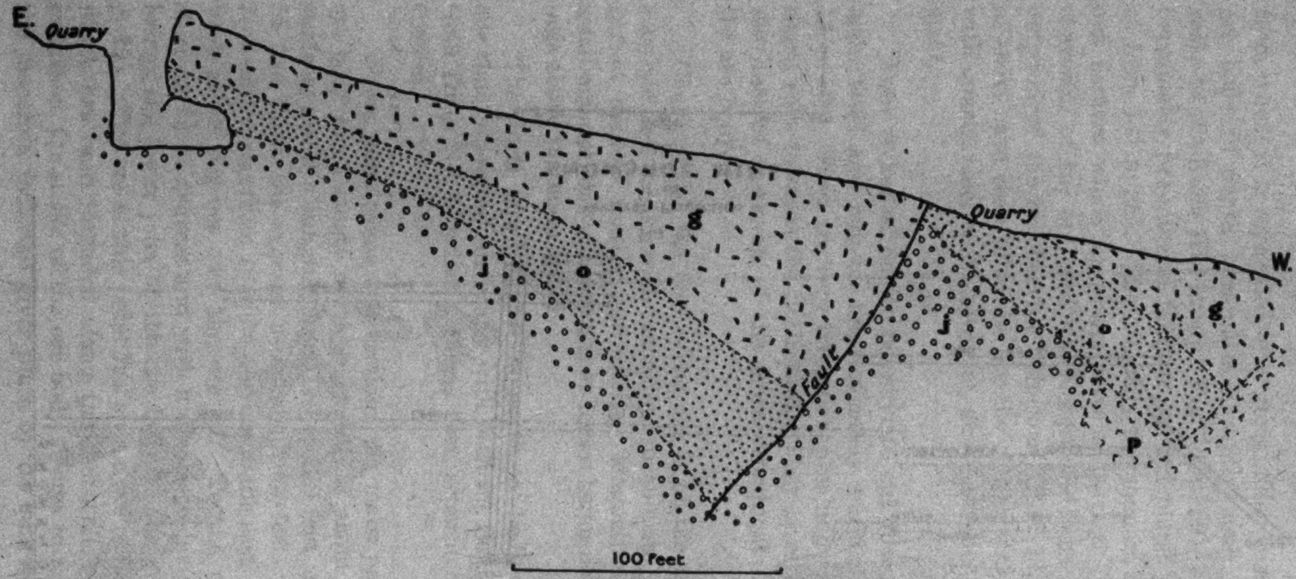

E.
Quarry
Quarry
W.
g
o
j
Fault
j
o
g
p
100 feet

Fig. 16.— Section, North Ore Body. Snowshoe Mine.
Ore (o), gangue rock (g), jasperoid (j), augite porphyrite (p).

Knob Hill group. The dip is to the southeast from 22 to 65 degrees, averaging about 45 degrees. The ore in this portion of the body was of a higher grade than the average mined in the camp, particularly in the copper content.

THE WAR EAGLE MINE.

Location.—The War Eagle mine of the Phoenix Amalgamated group is situated south of Phoenix, and adjoins the Aetna and Grey Eagle claims of the Granby Consolidated (Fig. 4, p. 54).

Development and Equipment.—The mine hasbeen developed by a two compartment vertical shaft sunk to the 100 foot level, which level has been connected to the surface by a 340 foot tunnel driven in from the south. The ore bins are 300 feet south of the portal of the tunnel, and are connected by a gravity tram line with a spur of the Canadian Pacific railway running in from Hartford junction. The surface work consists of a large amount of trenching along the outcrop of the mineralized zone. Air for power is supplied by the first half of a Rand duplex compressor, which is driven by one 80 horse-power horizontal tube boiler.

Geological Relations and Character of the Ore Bodies.—The main (100 foot) level lies below the mineralized zone in the country rock of jasperoid, except at the north end of No. 2 north cross-cut, where the ore was first encountered dipping at a low angle to the west and north. It consists of finely disseminated chalcopyrite and pyrite, in a dense epidotitic gangue, intermixed irregularly with coarser bands of ore in a gangue of grey calcite and quartz. A diamond drill hole through this ore body showed a vertical thickness of about 29 feet. Sufficient work has not been done to demonstrate the size and importance of this ore body.

In cross-cut No. 1 north a body of magnetite occurs about 33 feet above the main level, which is also exposed in surface cuts. From the present development the apparent dimensions of this body of magnetite would be about 135 feet along the strike, a width of about 160 feet on the dip, and a thickness of 35 feet and over. The dip is to the north at a low angle. The ore contains little or no copper, but pyrite is present in considerable amount.

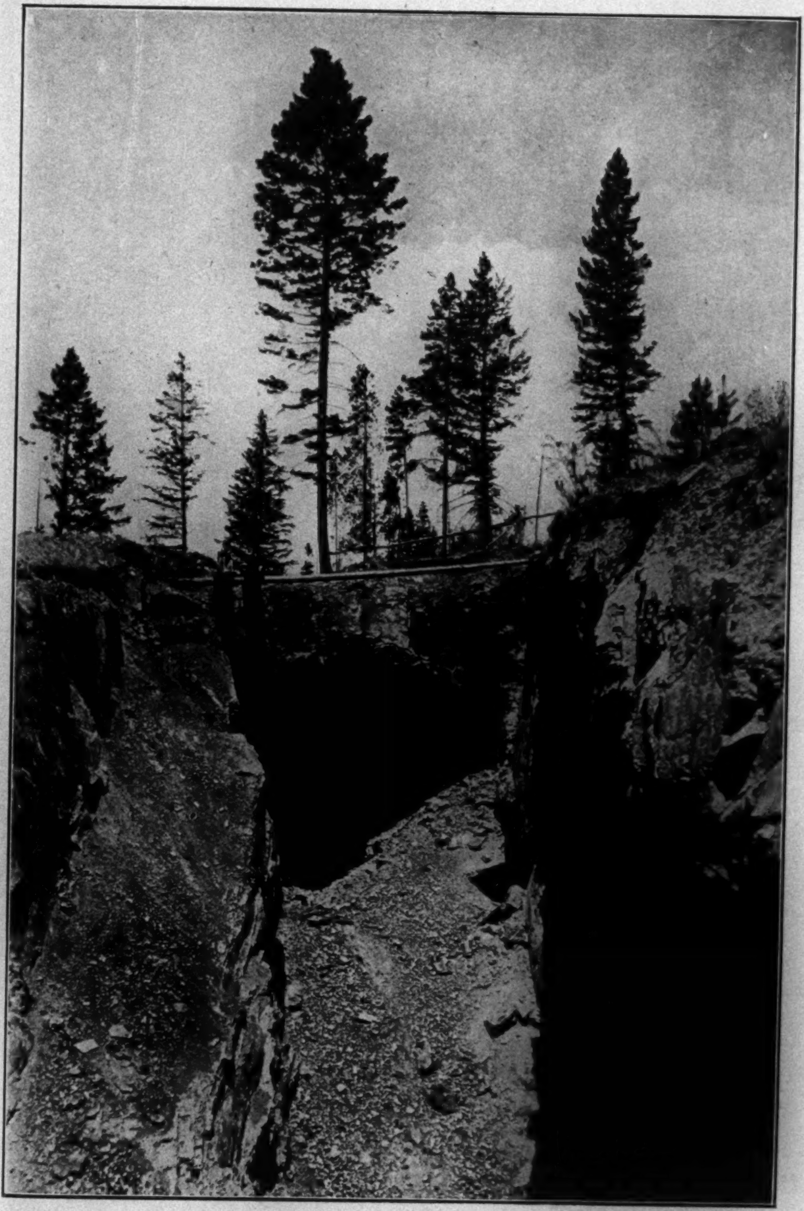
In the northeast corner of the claim, trenches Nos. 1 and 2 show a body of massive magnetite with pyrite. The surface width varies from 30 to 50 feet. The majority of the open-cuts show only lean ore or barren gangue, in places, marked by an abundance of massive olive green epidote containing pyrite and calcite.

As the ore bodies of the War Eagle are at or near the border of the mineralized zone, it is probable indications go to show that they will be relatively small, and separated from one another by barren wedges or ribs of the gangue rocks. The main ore body or bodies, if existing, will be found in the northwest corner of the claim, where the mineralized zone attains its greatest thickness on this property.

New Dominion Copper Company, Limited.

Location.—The Company owns the Brooklyn, Idaho, Standard, Stemwinder, Montezuma, and Rawhide claims situated in and in the vinicity of Phoenix, comprising in all about 177 acres (Fig. 4, p. 54).

History.—The Stemwinder was located by Attwood and Schofield about July 25, 1891, and the Brooklyn by Taylor and Mangott a few days later. The same season the Idaho was staked by Douglas and Dengler as the North Star, but was allowed to lapse as also was the ground covered by the present Rawhide located originally by G. W. Rumberger and his associates. In 1893 the Rawhide was relocated by McInnis and Gibbs and the Idaho by Rumberger in 1894. In 1898 it appears that Mackenzie and Mann secured a large interest in the Brooklyn, Stemwinder, Montezuma, and Standard and the following year the Dominion Copper Company of Canada was formed to develop the above properties, to which were added the Idaho and Rawhide. In 1894 this Company passed under the control of the Montreal and Boston Consolidated, who had, previous to this time, purchased the smelter at Boundary Falls with a capacity of 600 tons per day. In 1905 a reorganization was effected and the mines and smelter became the property of the Dominion Copper Company, Limited, of New York, who worked the mines intermittently until August, 1908. This Company was reorganized in 1909 as the New Dominion Copper Company, the controlling interest of which is



Brooklyn glory hole, 1909.

held by the British Columbia Copper Company, who are, next to the Granby Consolidated, the most important producers of copper in the Boundary district with producing mines in several of the adjacent camps and a complete smelting and converting plant at Greenwood.

Active mining operations were inaugurated on the Rawhide mine in June, 1910, and the mine has again become a steady shipper producing about 4,000 tons per week.

Production.—It was impossible to secure accurate data regarding the total production of the mines or the values in copper, gold, and silver. The best approximation available places the amount of ore mined and shipped at about 350,000 tons to January 1, 1911, of which about 180,000 tons were produced by the Rawhide mine.

Equipment.—The equipment with the exception of 30 drill duplex tandem compound Rand compressor and some of the pumping appliances is somewhat out of date and unsuitable for handling a large tonnage at a minimum cost. Under the present management, however, the plant is being entirely modernized.

Methods of Mining.—The Brooklyn, Idaho, and Stemwinder are so situated that a system of tunnels and 'glory holes' cannot be used to any great extent, nearly all the levels requiring shaft connexions for hoisting. The Rawhide is more favourably situated and can be developed entirely by tunnels and 'glory holes.' In the Brooklyn and Idaho, square setting of stopes has been superseded by the pillar and room system which has been used altogether in the Rawhide underground workings.

THE RAWHIDE MINE.

Location.—The Rawhide mine is the most important of the properties of the New Dominion and is situated to the southeast of the Gold Drop and south of the Snowshoe mine (Fig. 17, p. 96).

Development and Equipment.—The ore body has been developed by five 'glory holes' and six tunnels which are in the nature of cross-cuts and run in a westerly direction. The difference in elevation between No. 1 and No. 6 is 241 feet. About 3,500 feet (lineal) of work has been done in tunnels, drifts, crosscuts, and raises (Fig. 17, p. 96).

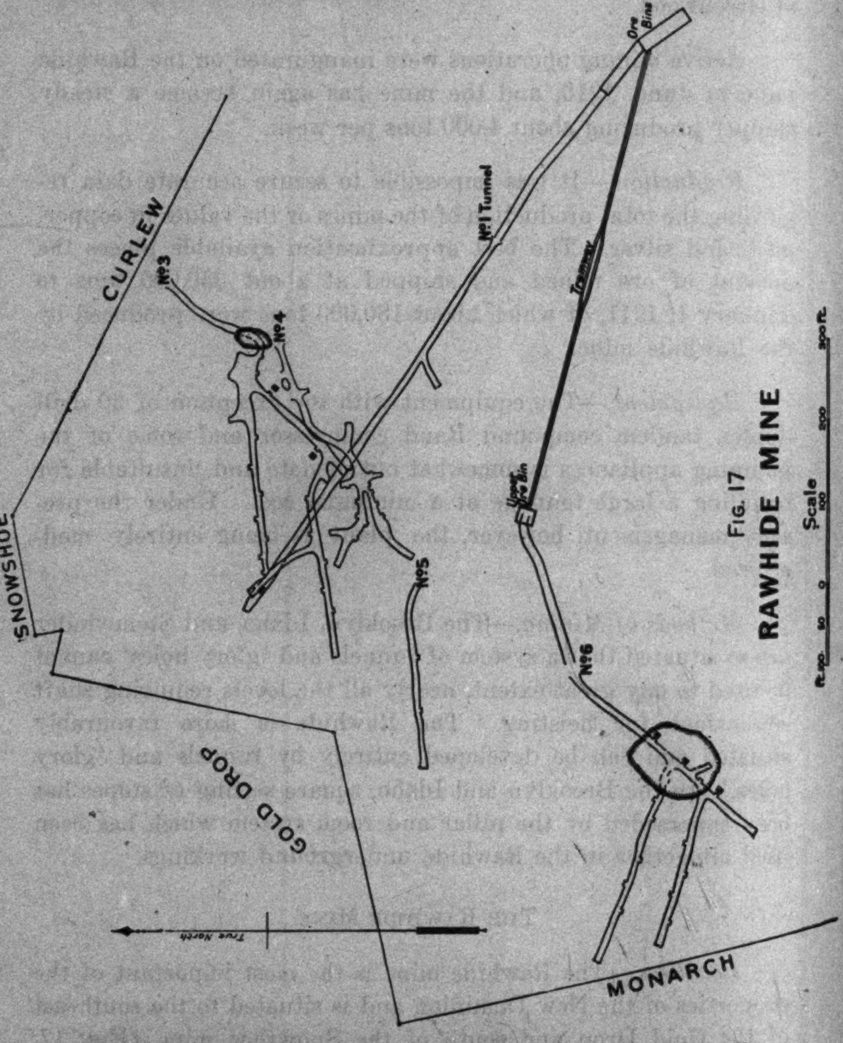

Ore Bins
No 1 Tunnel
Tramway
CURLEW
No 3
No 4
Upper Ore Bin
No 5
No 6
SNOWSHOE
GOLD DROP
MONARCH
True North
Scale
Ft. 100
50
0
100
200
300 Ft.

FIG. 17

RAWHIDE MINE

The ore bins are on a spur of the Canadian Pacific railway and are connected with No. 6 tunnel level by a balance gravity tramway. No. 1 tunnel is on the same level as the top of the ore bins and is the avenue of outlet for Nos. 3 and 4, the ore being dropped through a vertical raise. One ton cars have been used, and man haulage on the level grades, which will be superseded shortly by horses on the upper levels and electric haulage on the lower or No. 1 level.

Geological Relations and Character of the Ore Body.—The mineralized zone occupies the western part of the Rawhide claim, having an approximate area of 14 acres and a thickness ranging from a few inches to 75 feet.

The main ore body is a portion of the Gold Drop-Rawhide-Curlew-Snowshoe body discussed in a previous chapter (p. 81). In the stopes and 'glory holes' of No. 3 tunnel, the ore body as stoped on that level shows a length of at least 180 feet and a width of 35 feet. On the level of No. 4 tunnel, the ore body as stoped was 290 feet long, 120 feet wide, with an estimated thickness of from 20 to 30 feet. The 'glory hole' at No. 6 tunnel showed a face of gangue rock which contained some ribs of ore now stoped in great part. The results of recent drilling have proved the practical continuation of ore from No. 6 tunnel to the west and north boundaries of the claim. It is probable that the greater portion of the ore mined in future will be derived from the ground adjacent to the side lines of the Monarch, Gold Drop, and Curlew claims where the ore body probably attains its greatest thickness.

The ore body rests on a rolling floor of jasperoids and grey and reddish brown argillites and tuffs, the dip of the foot-wall being to the north and northeast at angles varying from 13° to 25°. With the exception of No. 4 (tunnel) most of the tunnel work has been under the ore, entailing higher raises in their western extensions to reach the ore.

Igneous Rocks.—Dykes of augite porphyrite occur on all levels and some outcrop at the surface (See General map). They vary in width from 1 to 16 feet and have apparently northerly trends. A small dyke of syenite porphyry—probably a phase of the granodiorite batholith—occurs cutting the foot-wall rocks in a cross-cut in No. 6 tunnel.

Character of the Ore.—The ore is similar to the average types in the camp described elsewhere. Garnet and epidote are the most prominent gangue minerals and chalcopyrite the only valuable metallic mineral.

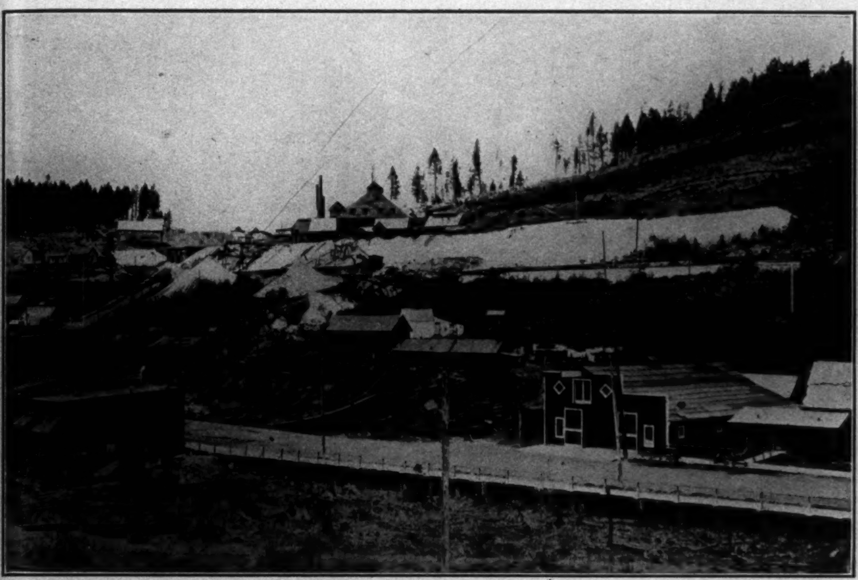
THE BROOKLYN-IDAHO MINE.

Location.—These two mines are adjacent on the same ore body or series of ore bodies and may thus be treated as a unit. They are situated in the western part of Phoenix and in part under the city. The Brooklyn is connected by a spur with the Canadian Pacific railway and the Idaho with the Great Northern railway.

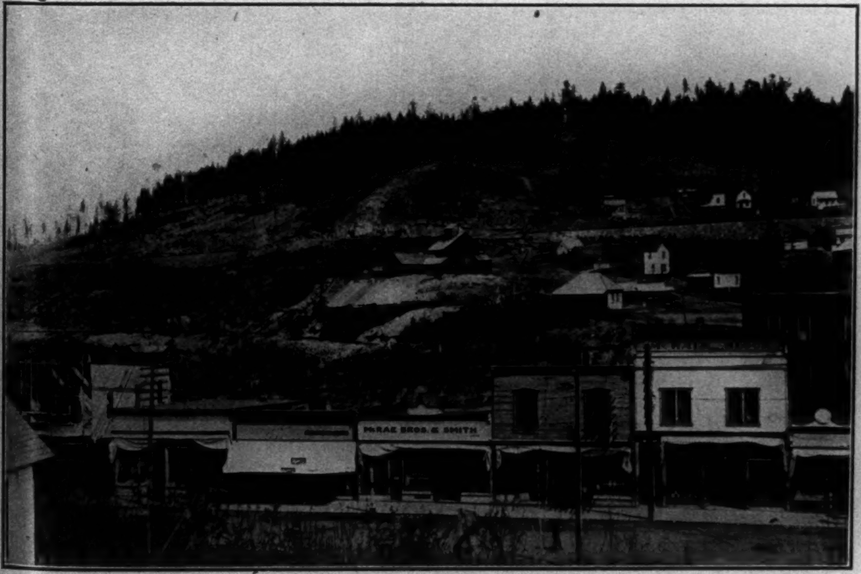
Development and Equipment.—The Brooklyn mine is opened on the surface by a 'glory hole' extending down to the 80 foot level, and the Idaho by two shallow open-cuts connected by raises to the No. 1 tunnel. Underground the Brooklyn mine is developed by an incline two compartment shaft 425 feet deep with levels at 80, 150, 250, and 350 feet respectively. A short intermediate was driven some distance south of the shaft at the 300 foot level. The ore is broken on grizzlies, dropped into pockets at the different levels and hoisted in 1·5 ton skips. Stoping too close to the surface caused a large cave south of the shaft some 310 feet long and up to 100 feet wide, extending below the 150 foot level and crushing parts of the 250 and 300 foot levels.

The Idaho mine is developed by a tunnel 480 feet long and an incline two compartment shaft with levels at 100 and 150 feet, the latter connected with and corresponding to the 250 foot level of the Brooklyn mine. About 7,500 feet (lineal) of drifting, cross-cuts, and raises has been done in the Brooklyn-Idaho mine.

Geological Relations and Character of the Ore Bodies.—The mineralized zone on the Brooklyn and Idaho claims has a length of about 1,850 feet with a surface width of 50 feet in the north to about 400 feet in the south, the form being that of an elongated pear. It lies on and is bounded by crystalline limestone and the rocks of the jasperoid zone (See General map). The main ore body measured from the north end of the Brooklyn 'glory hole' to the south end of the stopes of the 250 foot level is about 1,050 feet long, with a stoping width varying from 20 to 90 feet and a maximum depth of about 250 feet. South of this, smaller isolated bodies have been stoped in Nos. 8 and 9 stopes and in the open-cuts of the Idaho (Fig. 18, p. 99). A small body parallel to the main ore body and to the east of it outcrops in a

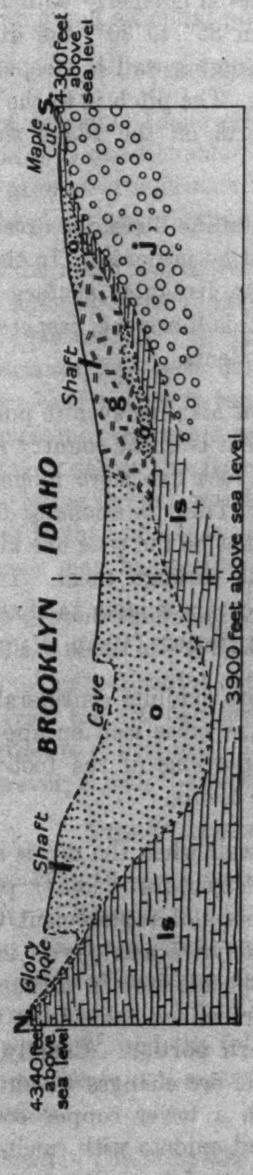


(*a*) Brooklyn mine, 1909.



McRAE BROS. & SMITH

(*b*) Stemwinder mine, 1909.


N
4340 feet above sea level
Glory hole
Shaft
ls
Cave
o
BROOKLYN IDAHO
ls
Shaft
g
j
Maple Cut
S
4300 feet above sea level
3900 feet above sea level

Scale · 400 feet to 1 inch

FIG. 18.—Generalized vertical projection of Brooklyn–Idaho

Ore bodies (o), limestone (ls), lightly mineralized or barren gangue (g), jasperoid (j).

railway cut and apparently continues as far as the 150 foot level.

The strike of the ore bodies is northerly with foot-wall dipping to the east ranging from 85° to 30°, the dip invariably flattening with depth. The hanging-wall is steeper throughout with dips of 55° and upwards. The pitch is to the south on the Brooklyn side and to the north on the Idaho side (Fig. 18, p. 99).

The foot-wall rock is crystalline limestone except in the extreme south when it is replaced by jasperoid. In the flatter portions the ore body rests on an irregular surface of limestone (Plate VI). The hanging-wall is limestone, jasperoid, tuffs and argillite or their sheared equivalents.

Intrusive dykes and sills of alkaline syenite porphyry (pulaskite) and augite porphyrite cut both the country rocks and ore bodies. Dykes of the former rock are more numerous and increase in number with depth. They occasionally form a structural wall which may or may not be the true one and in mining it is always advisable to break through them. The system of fissures running through the ore is similar to that already described under the general description (Chap. V, p. 58).

Character of Ore.—The ore exhibits considerable variation depending on its locality. It becomes lean on approaching the hanging-wall and also along portions of the foot-wall when a change in dip to a flatter grade occurs.

Along the limestone foot-wall when the dip is steep the ore is banded and preserves the structural (joint) planes of the country rock during the processes of replacement with ore. It consists of disseminated chalcopyrite and pyrite in grains and streaks with some hematite (specularite) in a granular quartz-calcite gangue. The richest ore mined came from the foot-wall side of the body in its northern portion. Usually, though not invariably, the character of the ore changes within a short distance from the foot-wall with a lower copper content and a gangue composed of garnet and epidote with calcite and quartz containing a greater proportion of hematite (specularite), an average analysis giving silica 39, lime 17, ferrous iron 14.

The ore in the southern part of the Idaho occurring in the tunnel and open-cuts appears to be very low grade, probably below the mining and shipping point.

FUTURE POSSIBILITIES.

The main Brooklyn-Idaho ore body has been stoped out in great part and it is questionable if any ore bodies will be found in adjoining ground of sufficient importance to warrant the reopening of the mine under existing conditions.

Towards the north end of the Brooklyn, ore occurs back of the foot and hanging-walls proper in small isolated bunches of almost solid chalcopyrite. So far, however, no body of commercial importance has been discovered outside of the walls. Beyond the ore body proper in the north of the Brooklyn, pyritic crystalline limestone occurs in a raise from the 150 foot level. A sample was taken across the face and an assay made by H. A. Leverin of the Mines Branch, which gave 0·3 ounce of gold and 0·4 ounce of silver to the ton. It is possible that a considerable portion of this zone may be considered important enough to stope.

The only ground that might be considered worth diamond drilling is a block south of the 250 foot stopes and west of stopes Nos. 8 and 9. The horizontal diamond drill hole 411 feet long drilled west from the 350 foot level is not conclusive, as it is at too low a horizon to expect ore. The present development of the mine has, however, shown the vertical limits of the ore bodies.

THE STEMWINDER MINE.

Location.—The Stemwinder mine is situated in the central part of the city of Phoenix and to the east of the Brooklyn. The mine has been idle for several years, and being filled with water it was not possible to examine any of the workings except the 'glory hole' and tunnel. Little information was available regarding the property, and the following, for the most part, has been taken from the annual reports of the Minister of Mines for British Columbia.

Development.—The mine has been opened by a 'glory hole,' tunnel and incline shaft stated to be 400 feet deep. At the 100 foot level a cross-cut was run for 75 feet and a winze stated to be sunk in ore for 25 feet. At 114 feet another cross-cut was run which is stated to have cut two ore bodies, the widths on that level being 18 and 30 feet respectively.

The tunnel is southwest of the shaft and about 250 feet below the collar. It cuts a band of lean ore 6 to 8 feet wide about 90 feet in from the portal.

Geological Relations and Character of the Ore Bodies.—The ore body is situated along the western border of a lens of crystalline limestone (See General map), which is much brecciated and in part replaced by epidote and quartz. The ore body appeared to have been practically vertical with a north strike, and in mining it, a 'glory hole' 110 feet long, 60 feet wide, and 30 to 40 feet deep has been stoped out. It cannot be stated whether the ore occurring at lower levels belongs to this surface body or occurs in isolated lenses in the mineralized zone.

Character of the Ore.—In specimens taken from the dump, the ore is seen to consist of chalcopyrite in large grains and lenses up to an inch or so wide and several inches long, associated with hematite (specularite) and pyrite. The gangue is essentially grey calcite with small amounts of epidote and quartz. The surface ore, in part, was stated to be comparatively rich, particularly in its gold content.

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Canada
Department of Mines
GEOLOGICAL SURVEY

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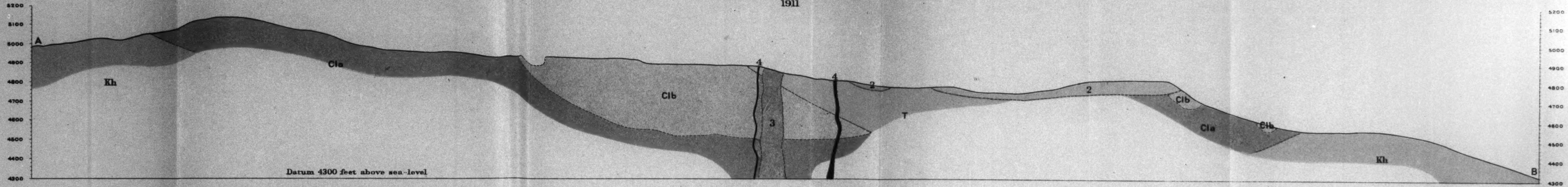
R. W. BROCK, DIRECTOR.

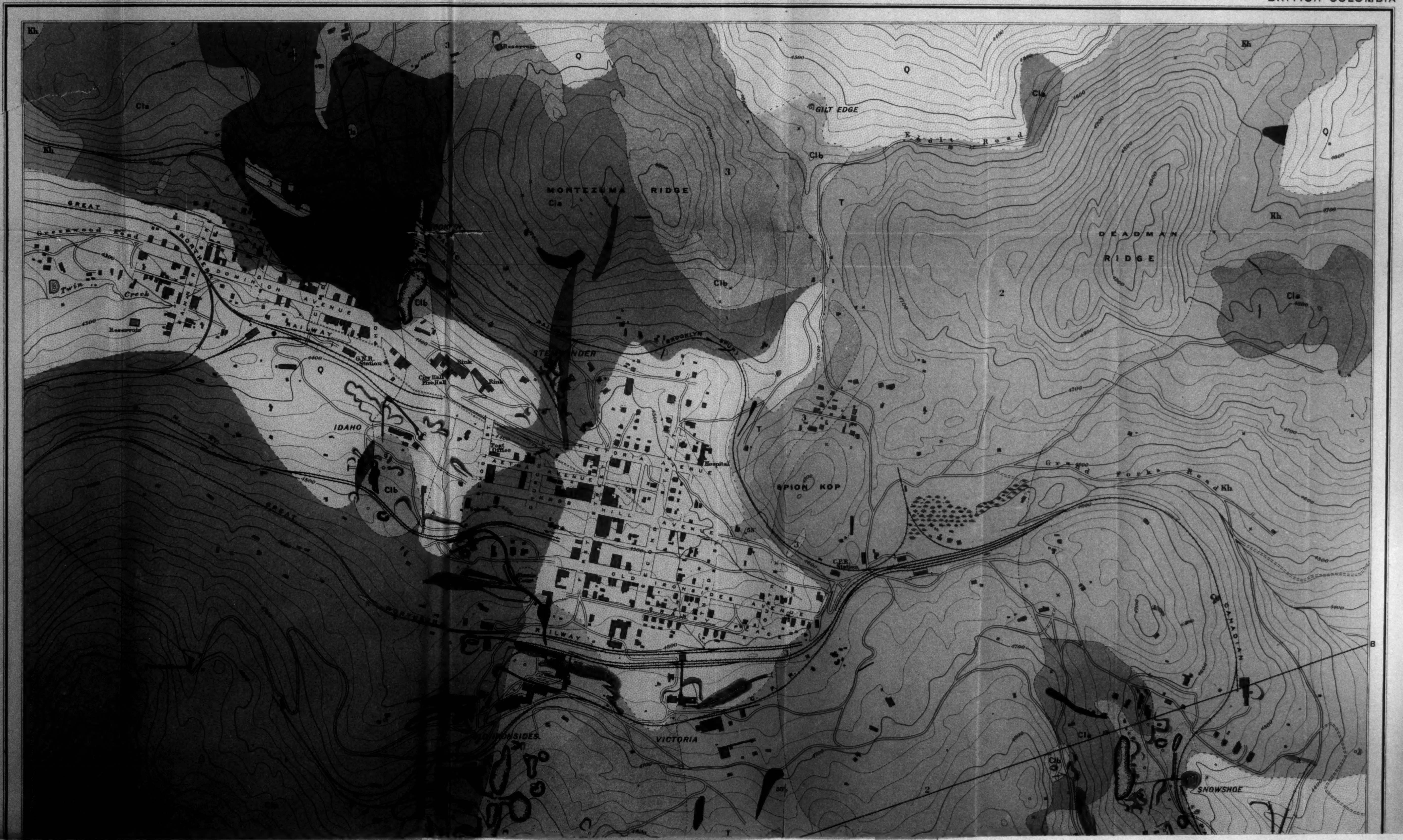
1911


A
B
Clα
Kh
Clb
3
4
2
T
Datum 4300 feet above sea-level
5200
5100
5000
4900
4800
4700
4600
4500
4400
4300

Structural section along line AB
Scale, horizontal and vertical, 400 feet to 1 inch

GEOLOGY

BRITISH COLUMBIA


MONTEZUMA RIDGE
DEADMAN RIDGE
SPION KOP
GILT EDGE
IDAHO
VICTORIA
SNOWSHOE
IRONSIDES
STEMWINDER
Greenwood Road
Twin Creek
Grand Forks Road
GREAT NORTHERN RAILWAY
C.P.R. Station
G.N.R. Station
City Hall
Fire Hall
Post Office
Hospital
Reservoir
Q
Kh
Clα
Clb
T
2
3
B

LEGEND

QUATERNARY

- Q — Clay, sand and gravel

TERTIARY — MIOCENE(?)

- Pulaskite porphyry (alkaline syenite porphyry) Dikes and sills
- 3 — Augite porphyrite (dikes, sills and stocks)
- 2 — Midway Volcanic group (Trachyte flows)

TERTIARY — OLIGOCENE

- T — Kettle River formation (conglomerate, sandstone and shale)

MESOZOIC — JURASSIC(?)

- Syenite and syenite porphyry (masses and dikes)

PALEOZOIC — CARBONIFEROUS(?) — ATTWOOD SERIES

- Rawhide formation (argillite)
- Clb — Brooklyn formation (Mineral zone, containing ore deposits)
- Brooklyn formation (zone of jasperoids)
- Brooklyn formation (crystalline limestone)
- Knob Hill group (dark rock, tuff, chert and porphyrite)

LEGEND

Culture

- Roads and buildings
- Roads not well defined
- Railways
- Mine tramways
- Elevated tramways
- Aerial tramways
- Bridges
- Elevated buildings
- Shaft houses
- Shafts
- Mine tunnels
- Prospects
- Dams
- Water tanks
- Cribwork
- Glory holes

Water

TERTI

MESOZOIC

PALEOZOIC

JURASSIC(?) OLIGOCENE

CARBONIFEROUS(?)

ATTWOOD SERIES

Midway Volcanic group
(Trachyte flows)

T **Kettle River formation**
(conglomerate, sandstone and shale)

Syenite and syenite porphyry
(masses and dikes)

C2 **Rawhide formation**
(argillite)

Clb **Brooklyn formation**
(Mineral zone, containing ore deposits)

Cla **Brooklyn formation**
(zone of jasperoids)

C **Brooklyn formation**
(crystalline limestone)

Kh **Knob Hill group**
(Ash rock, tuff, chert and porphyrite)

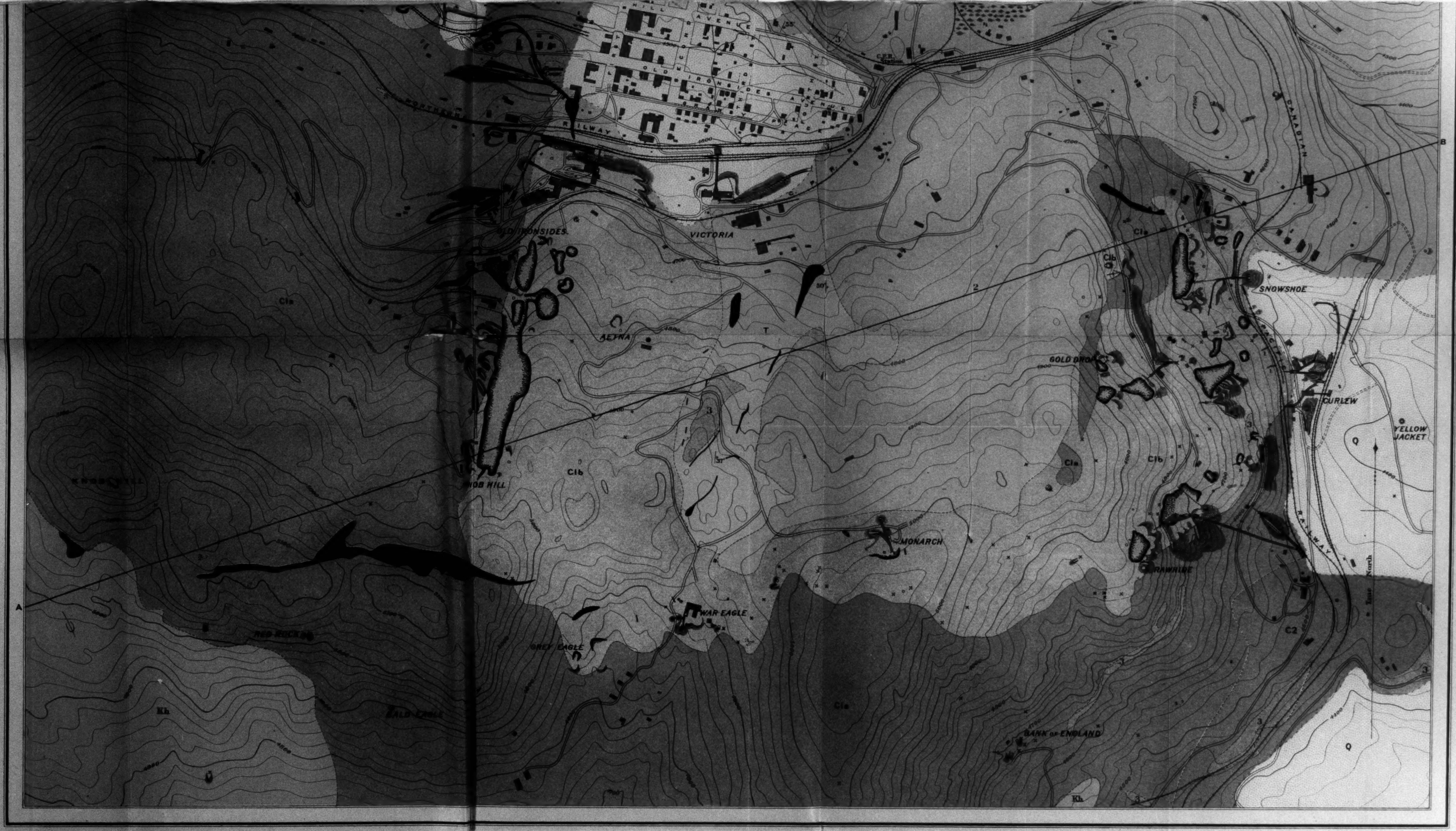
Symbols

Geological boundary
(located within 20 feet of actual contact)

Geological boundary
(assumed)

50° **Dip and strike**

Glacial striae



A
B
OLD IRONSIDES
VICTORIA
AETNA
KNOB HILL
MONARCH
WAR EAGLE
GREY EAGLE
GOLD DROP
SNOWSHOE
CURLEW
YELLOW JACKET
RAWHIDE
BANK OF ENGLAND
CANADIAN PACIFIC RAILWAY
NORTHERN RAILWAY
OLD IRONSIDES AVENUE
True North
Clb
Cla
Kh
C2
T
Q

Elevated buildings

Shaft houses

Shafts

Mine tunnels

Prospects

Dams

Water tanks

Cribwork

Glory holes

Water

Streams

Flumes

Marshes

Relief

Contours
(showing land forms and elevations above sea-level)
Interval 20 feet

Depression contours

Mine dumps

Contours showing heights above sea-level based on an elevation supplied by the Granby Mining Co.

Magnetic declination about 24° East.

C.O. Senécal, *Geographer and Chief Draughtsman.*

Nelson
West Robson
Christina L.
Phoenix
Grand Forks
Rossland
Trail
Salmo
Eholt
Midway

Scale: 35 Miles to 1 Inch

MAP 16A

PHOENIX

BRITISH COLUMBIA

Scale . $\frac{1}{4,800}$

Feet
400 200 0 400 800 1200
Metres
100 0 100 200 300 400

400 FEET TO 1 INCH

GEOLOGY
O. E. LEROY. 1908

TOPOGRAPHY
W. H. BOYD, (IN CHARGE) 1908
G. G. AITKEN, COMPILER

To accompany Memoir No. 21

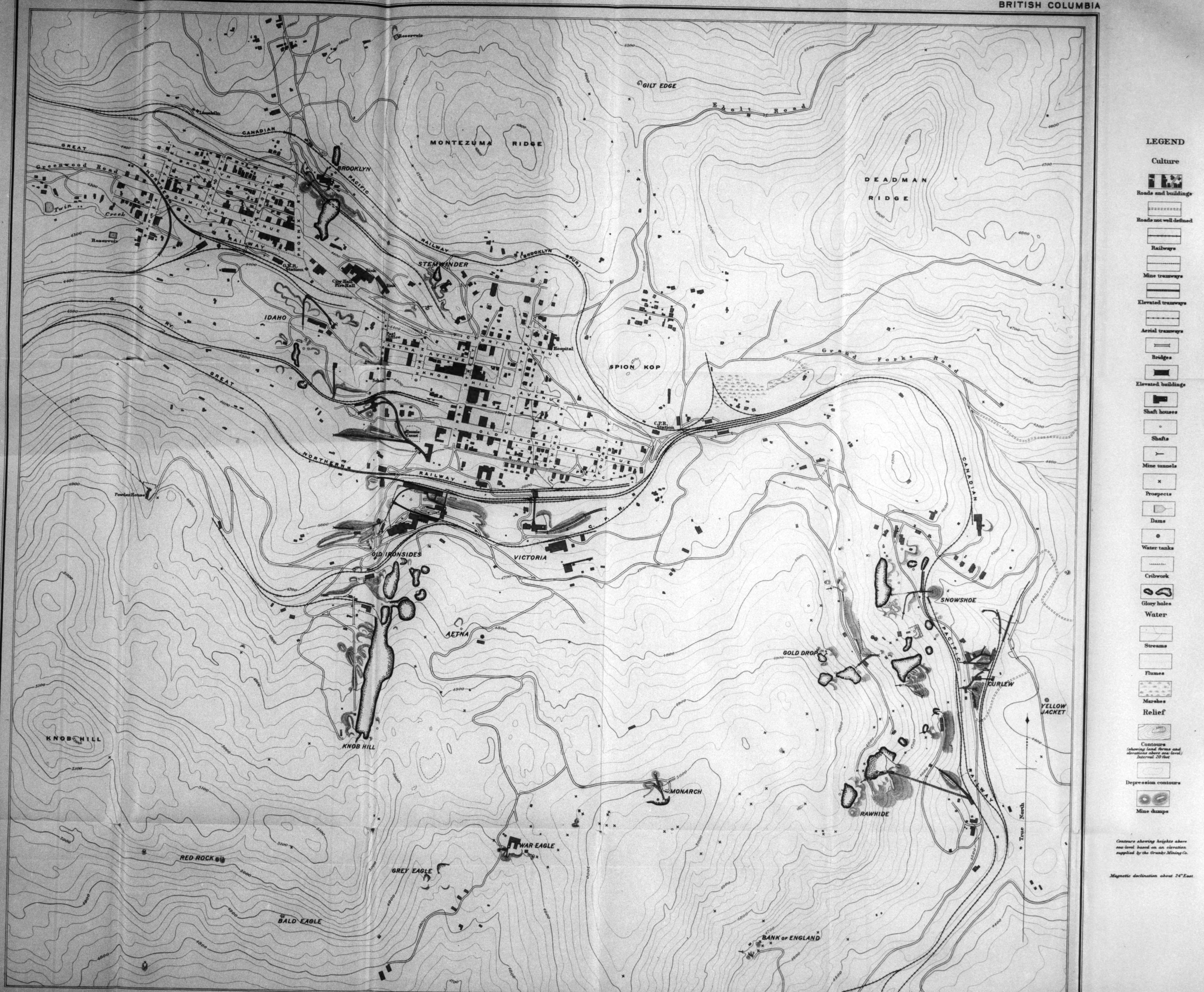
Canada
Department of Mines
GEOLOGICAL SURVEY

HON. W. TEMPLEMAN, MINISTER; A. P. LOW, DEPUTY MINISTER;
R. W. BROCK, DIRECTOR.

1911

TOPOGRAPHY

BRITISH COLUMBIA


MONTEZUMA RIDGE
GILT EDGE
Eholt Road
DEADMAN RIDGE
Greenwood Road
Twin Creek
Reservoir
CANADIAN PACIFIC RAILWAY
GREAT NORTHERN RAILWAY
BROOKLYN
BROOKLYN SPUR
STEMWINDER
G.N.R. Station
City Hall
Fire Hall
IDAHO
Hospital
SPION KOP
Grand Forks Road
C.P.R. Station
Powder House
OLD IRONSIDES
VICTORIA
SNOWSHOE
AETNA
GOLD DROP
CURLEW
YELLOW JACKET
KNOB HILL
KNOB HILL
MONARCH
RAWHIDE
WAR EAGLE
GREY EAGLE
RED ROCK
BALD EAGLE
BANK OF ENGLAND
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LEGEND
Culture
Roads and buildings
Roads not well defined
Railways
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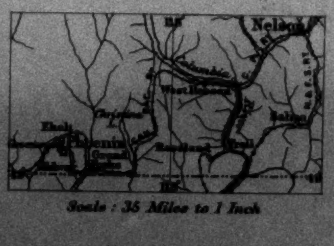
Elevated tramways
Aerial tramways
Bridges
Elevated buildings
Shaft houses
Shafts
Mine tunnels
Prospects
Dams
Water tanks
Cribwork
Glory holes
Water
Streams
Flumes
Marshes
Relief
Contours (showing land forms and elevations above sea-level) Interval 20 feet
Depression contours
Mine dumps

Contours showing heights above sea-level based on an elevation supplied by the Granby Mining Co.

Magnetic declination about 24° East.

C.O. Senécal, Geographer and Chief Draughtsman.


Nelson
Eholt
Phoenix

Scale : 35 Miles to 1 Inch

MAP 15A

PHOENIX
BRITISH COLUMBIA

Scale $\frac{1}{4800}$

Feet: 400 200 0 400 800 1200

Metres: 100 0 100 200 300 400

400 FEET TO 1 INCH

TOPOGRAPHY

W. H. BOYD, (IN CHARGE) 1908

G. G. AITKEN, COMPILER

To accompany Memoir No. 21